Climatology of Florida Winter Season Tornadoes for ENSO, AO, and PDO Patterns

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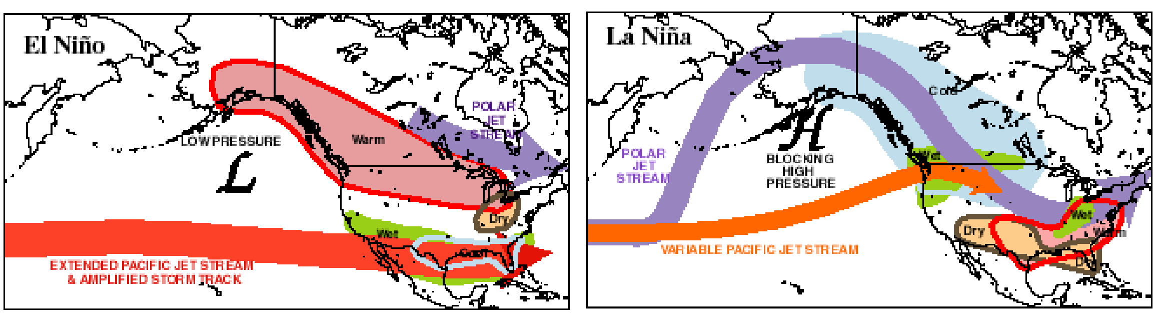
Abstract

This study investigates the frequency and intensity of Florida winter season tornadoes and possible relationship between El Niño/La Niña, the Arctic Oscillation (AO), and the Pacific Decadal Oscillation (PDO). A hypothesis that there would be a change in the frequency and intensity of winter season tornadoes in Florida over opposite phases of teleconnection patterns was formulated and tested based on the changing strength and position of the subtropical and polar jet streams. Results show there is not a significant difference in the number and intensity of tornadoes for any phase of the teleconnection patterns studied. A change in spatial distribution of tornadoes does appear graphically for ENSO events but not for the AO or PDO.

1. Introduction

The Southern Oscillation is a vacillation of atmospheric mass between a region of high pressure in the eastern South Pacific and a region of low pressure in the Indo-Australian Pacific that is caused by interannual variation of tropical Pacific sea surface temperature (Quinn and Neal 1987). El Niño is associated with warm sea surface temperature (SST) anomalies in the central and eastern Pacific. The term La Niña applies to the presence of cold SST anomalies in the eastern Pacific.

Changes in the tropics lead to atmospheric circulation anomalies or teleconnections (Marzan and Schaefer 2001). During an El Niño winter there is an equatorial displacement of the polar jet stream and intensification of the subtropical jet stream leading to increased moisture advection and precipitation in the southeast U.S. (Ropelewsi and Halpert 1986). During a La Niña event the polar jet is displaced poleward leading to a decrease in precipitation in the southeast United States (Fig. 1).



(a) (b)

FIG 1. The climatological position and intensity of North American jet streams during (a) El Niño and (b) La Niña phase are depicted along with associated weather features. (from CPC 2003)

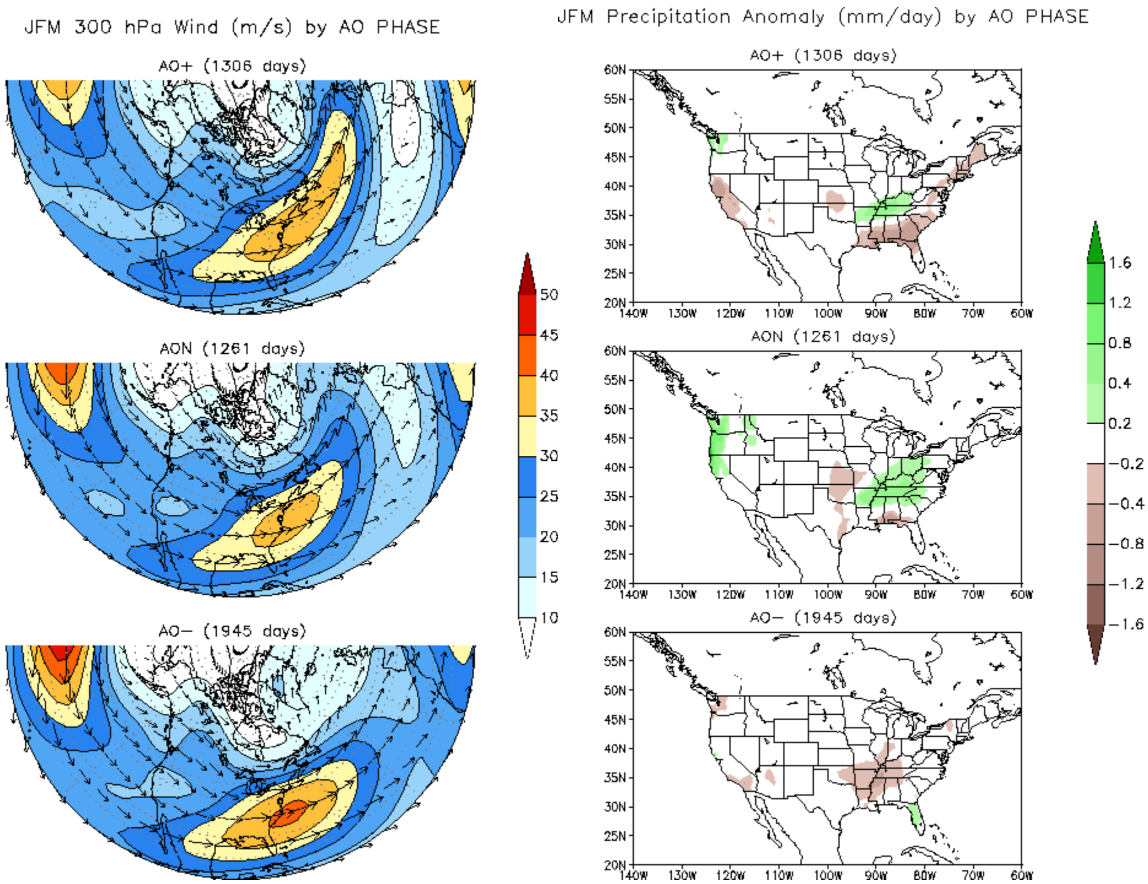
The Arctic oscillation (AO) is a pattern in which atmospheric pressure in northern latitudes fluctuates between positive and negative phases. The negative phase is correlated with higher pressure over the polar region and lower pressure around 45 degrees north latitude. The opposite occurs in the positive phase resulting in anomalously weak westerly winds. The negative phase of the AO tends to be associated with polar outbreaks in the United States (Walsh et al 2001). An intensification and equatorward displacement of the polar jet as well as an increase in Florida precipitation during the AO negative winter season are observed on the AO composite analysis from the Climate Prediction Center (2003; Fig. 2). The observed increase in precipitation may be the result of a general area of increased upper-air divergence associated with the right entrance region of the "climatological jet streak".

The PDO is a long lived ENSO-like oscillation of SST in the North Pacific. A phase of the PDO can persist for 20 to 30 years versus 6 to 18 months for a typical phase of ENSO. The cause of the PDO is unknown and its associated affects on U.S. weather patterns are not as thoroughly researched and understood as ENSO or the AO.

Teleconnection induced changes in the position and intensity of the jet stream related to and associated change in atmospheric stability could potentially be reflected in southeast U.S. tornado climatology. This study examines the potential relationship between El Niño/La Niña, the AO, PDO and tornado frequency and intensity in Florida.

Impact on tornado climatology from atmospheric teleconnection patterns has not been widely studied with the exception of ENSO. Marzban and Schaefer (2001) discuss several informal papers regarding the possible relationship between ENSO and tornado frequency in the United States (Bove 1998, Browning 1998, Agee and Zurn-Birkhimer 1998, Hegemeyer, 1998, Schaefer and Tatom 1998). Differing methods employed in each study resulted in varying results due to the imprecise definition of El Niño and La Niña and conflict as to whether or not either condition existed during a particular year.

Marzban and Schafer (2001) suggest differing methods assessing and identifying warm or cold SST anomalies and the likelihood that a warm or cold anomaly can begin in one year and terminate during the next further complicate methods and results.



(a) (b)

FIG 2. Arctic Oscillation (a) Winter season 300 hPa wind in m/s and (b) precipitation anomalies. (from CPC 2003)

2. Methods

Data from the Climate Prediction Center (2003) are used to classify El Niño, La Niña, and neutral events (Table 1). The Climate Prediction Center (CPC) subjectively classifies the intensity of each event by focusing on SST along the equator from 150°W to the date line. Seasonally averaged data for the AO (Fig. 3) and PDO were obtained from the Joint Institute for the Study of the Atmosphere and Ocean (2003). Tornado data from the National Climatic Data Center (2003) for the years 1953 – 2002 are analyzed by the January, February, and March winter season for each teleconnection phase. The seasonal method will eliminate ambiguities related to ENSO events occurring in portions of multiple calendar years. In addition, limiting the time of study to specified months will eliminate a signal from hurricanes which Grey (1984) has noted tend to decrease in frequency during El Niño years and increase in frequency during La Niña years.

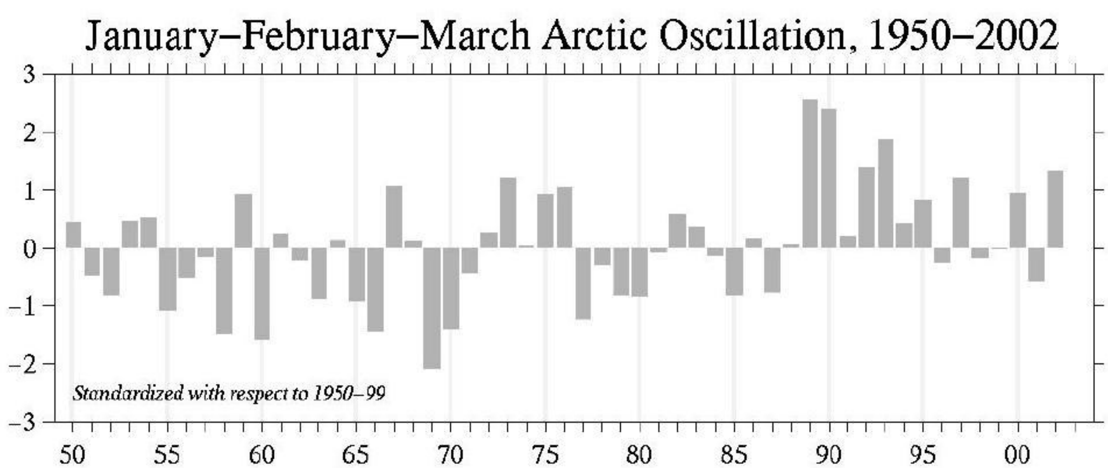


FIG 3. Seasonally averaged Arctic Oscillation index values. (from Joint Institute for the Study of the Atmosphere and Ocean 2003)

In order to establish a tornado climatology for Florida, records of F1 and greater intensity tornadoes and F2 and greater intensity tornadoes (refer to table 2 for F-scale classification and intensity description) are plotted and analyzed for each teleconnection phase: El Niño (Fig. 4); La Niña (Fig. 5); ENSO neutral (Fig. 6); AO positive (Fig. 7); AO negative (Fig. 8); PDO negative (Fig. 9); and PDO positive (Fig. 10). A tornado that crossed a county boundary is counted as an occurrence for each county. Records of F0 tornadoes are neglected in all cases primarily because the probability of detection of an F0 tornado following 1988 is significantly higher than previous years. This is likely due to the introduction of the WSR-88D radar (McCarthy 2001) as well as an increase in number of trained storm spotters (Doswell et al. 1999). Further problems, as discussed by Doswell and Burgess (1988), associated with establishing a climatology of tornadoes include the problem of distinguishing between long-track tornadoes versus successive tornadoes (where a tornado develops, dissipates, then redevelops) and F-scale reporting biases should average over the long term given the cyclical nature of ENSO and the AO with time. The exception would be the PDO where the earliest half of study years is dominated by the negative phase with the latter half dominated by the positive phase.

3. Results

ENSO

There are 133 tornadoes recorded during 16 January through March El Niño seasons (Fig. 1). The average number of F1 or greater intensity tornadoes per El Niño season is 8.3 with a standard deviation of 9.8. Of these, 39.1% are rated F2 or greater intensity. Over the course of 14 La Niña seasons 76 F1 or greater intensity tornadoes were recorded yielding a seasonal average of 5.4 and standard deviation of 5.7 (Fig 2). The percentage of F2 or greater intensity tornadoes during the La Niña winter season is 39.4. During 20 ENSO neutral seasons there were 102 F1 or greater intensity tornadoes (Fig. 3). The seasonal average is 5.1 with a standard deviation of 5.9. The percentage of F2 and greater intensity tornadoes during ENSO neutral seasons is 31.4%.

Student-t tests were conducted in order to determine if the number of F1 or greater intensity tornadoes between El Niño, La Niña, and neutral seasons are significantly different. There is not a significant difference at the 95% confidence level between the number of Florida tornadoes during El Niño seasons and neutral seasons, nor is there a significant difference between the number of El Niño season tornadoes and La Niña season tornadoes. Furthermore, there is not a significant difference between the number of La Niña season tornadoes and neutral season tornadoes. The ratios of F2 and greater intensity tornadoes to F1 and greater intensity tornadoes for El Niño and La Niña events are almost identical. The percentage of F2 tornadoes during ENSO neutral events is slightly less than for El Niño and La Niña events.

Graphically, there are more tornadoes recorded in central and southern Florida for El Niño seasons than La Niña seasons (Fig. 1 – 2). The difference is most pronounced for F2 and greater intensity tornadoes. During La Niña and ENSO neutral seasons there are more tornadoes reported in the Florida panhandle than for El Niño seasons (Fig. 1 – 3).

AO

There are 235 tornadoes recorded during 33 January through March AO negative dominant seasons. The average number of F1 or greater intensity tornadoes per AO negative season is 7.1 with a standard deviation of 7.9. Eighty three tornadoes (35.3%) are rated F2 or greater intensity. Over the course of 17 AO positive dominant seasons 77 F1 or greater intensity tornadoes were recorded yielding a seasonal average of 4.5 and standard deviation of 5.8. Seventeen of the cases (22%) were F2 or greater intensity.

Student-t tests conducted do not show a significant difference at the 95% confidence level between the number of F1 or greater intensity Florida tornadoes during AO negative dominant seasons and AO positive dominant seasons. The ratios of F2 and greater intensity tornadoes to F1 and greater intensity tornadoes for AO negative and AO positive dominant seasons appreciably differ, however, sampling is limited for AO positive seasons. Graphically, a change in spatial distribution of tornadoes is not evident in Florida for AO negative and AO positive seasons.

PDO

There are 176 tornadoes recorded during 23 January through March PDO positive dominant seasons. The average number of F1 or greater intensity tornadoes per PDO positive season is 7.7 with a standard deviation of 8.0. The percentage of tornadoes rated F2 or greater intensity is 36.9%. Over the course of 127 PDO negative dominant seasons 136 F1 or greater intensity tornadoes were recorded yielding a seasonal average of 5.0 and standard deviation of 6.6. Forty-seven of the cases (34.6%) were F2 or greater intensity.

Student-t tests conducted do not show a significant difference at the 95% confidence level between the number of F1 or greater intensity Florida tornadoes during PDO positive dominant seasons and PDO negative dominant seasons. The ratios of F2 and greater intensity tornadoes to F1 and greater intensity tornadoes for PDO negative positive dominant seasons are very similar suggesting a change in tornado intensity is not likely. Graphically, a change in spatial distribution of tornadoes is not evident in Florida between PDO positive and PDO negative seasons. Caution is expressed for the PDO results as there has only been one complete cycle during the time of study.

4. Discussion

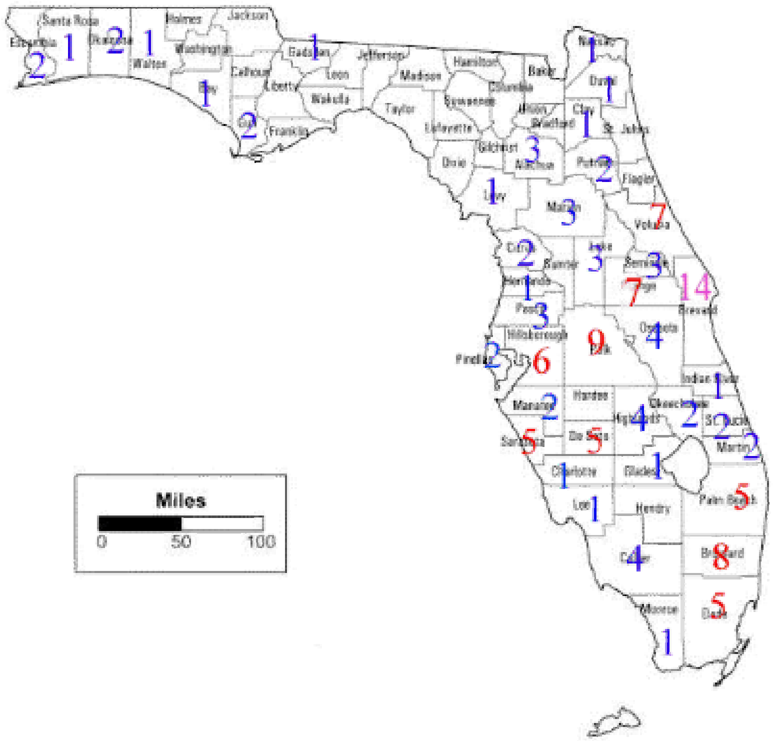
There is not a significant difference at the 95% confidence level in the number of total number of Florida tornadoes between El Niño, La Niña and neutral winter season events. A spatial difference may exist but given the limited number of tornadoes and ENSO events sampling becomes poor at a more local level. Spatial trends, if they exist, tend to follow the climatological shift in the jet steam with El Niño and La Niña events. The two seasons with the greatest number of tornadoes in both categories were 1983 and 1998, years with strong El Niño episodes during the winter season (Table 1). The 1972 neutral season and 1975 weak La Niña seasons, however, also had a large number of tornadoes reported. Furthermore, three El Niño seasons had no tornadoes reported and two seasons had only one tornado reported.

Like ENSO events, differences between the AO and PDO phases were not significant at the 95% confidence level. There does not appear to be any spatial trend with either phase of the AO or PDO. The ratio of F2 to F1 and greater intensity tornadoes during AO positive dominant seasons is appreciably less than the negative phase but limited sampling could be a factor. The ratios of F2 to F1 tornadoes between PDO phases are very similar suggesting there is not an increase in tornado intensity for a PDO phase change.

The warm phase of ENSO has the highest mean number of tornadoes of all teleconnection patterns discussed. The warm ENSO phase mean is 8.3 tornadoes per three-month winter season versus a mean of 6.2 tornadoes per three-month winter season for the duration of the 50-years of study. The positive phase of the PDO has the next highest seasonal mean of 7.7 followed by the negative phase of the AO at 7.1. The AO positive phase has the lowest mean number of 4.5 followed by the negative PDO phase at 5.0 and ENSO neutral episodes at 5.1 F1 or greater intensity tornadoes per season.

5. Conclusions

The hypothesis that there would be a change in the frequency tornadoes associated with different teleconnection phases is not supported at the 95% confidence level. The ratios of F1 and greater intensity and F2 and greater intensity tornadoes for El Niño/La Niña and PDO positive/negative seasons are nearly identical suggesting there is not an increase in intensity of tornadoes during opposite phases. Similarly one can not say with 95% confidence that differences in Florida tornado climatology associated with opposite phases of the AO and PDO are significant. Spatial changes are not apparent with opposite AO and PDO phases however a change may exist for ENSO phases. Given the fact that tornadoes are relatively rare events, expansion of the data set into surrounding states could provide further insight.



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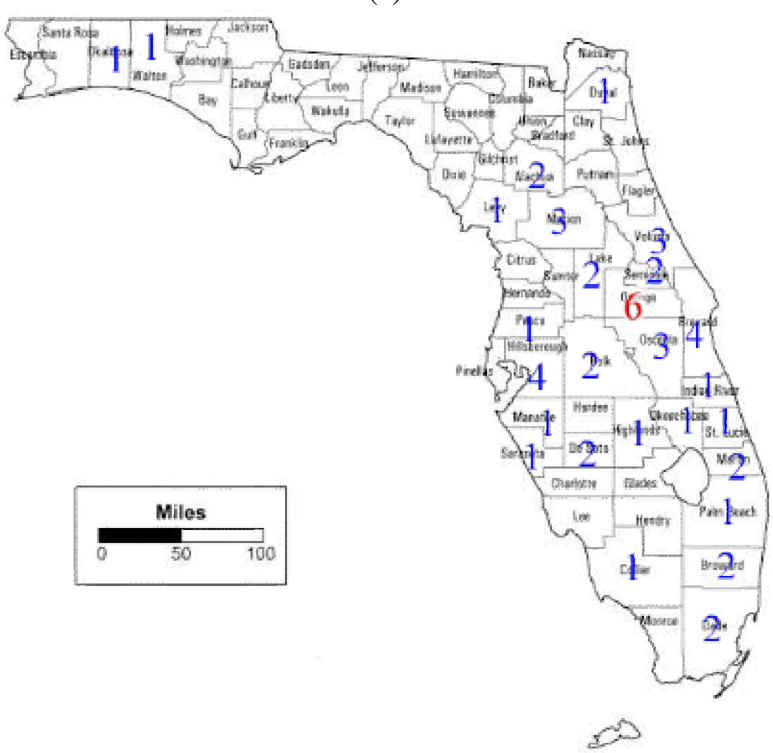

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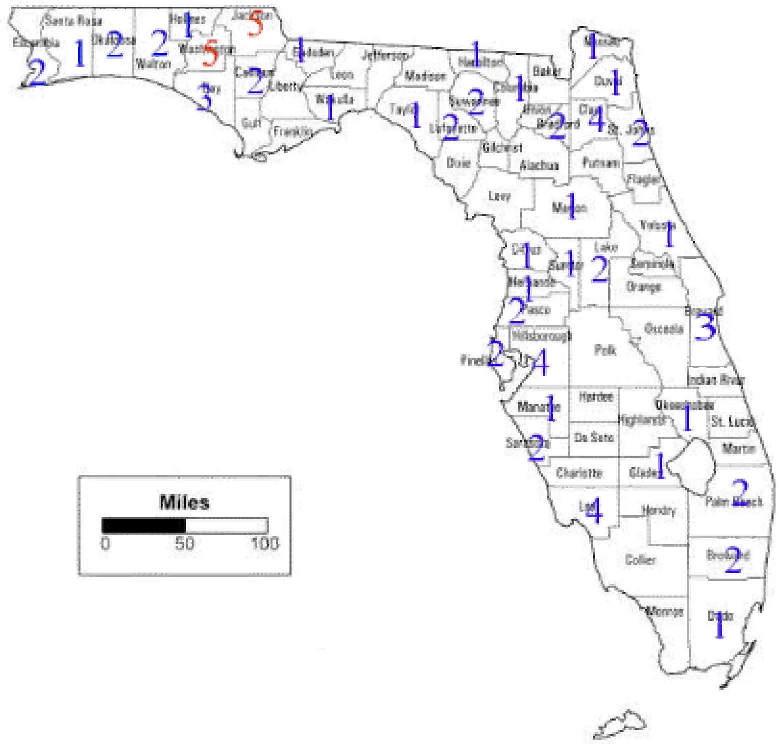
FIG 4. The total number of (a) F1 and greater intensity tornadoes and (b) F2 and greater intensity tornadoes that occurred during all El Niño years in each Florida county.



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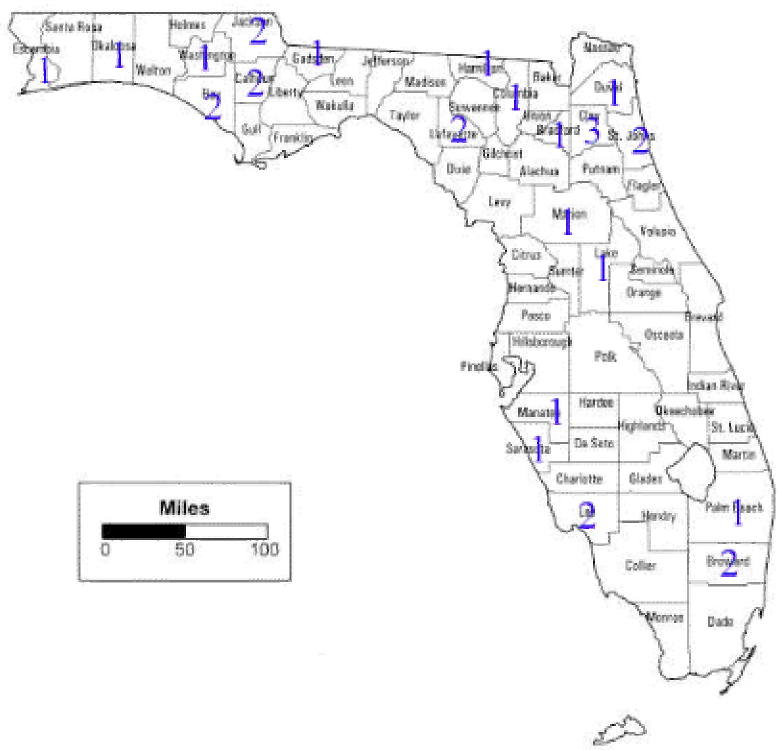

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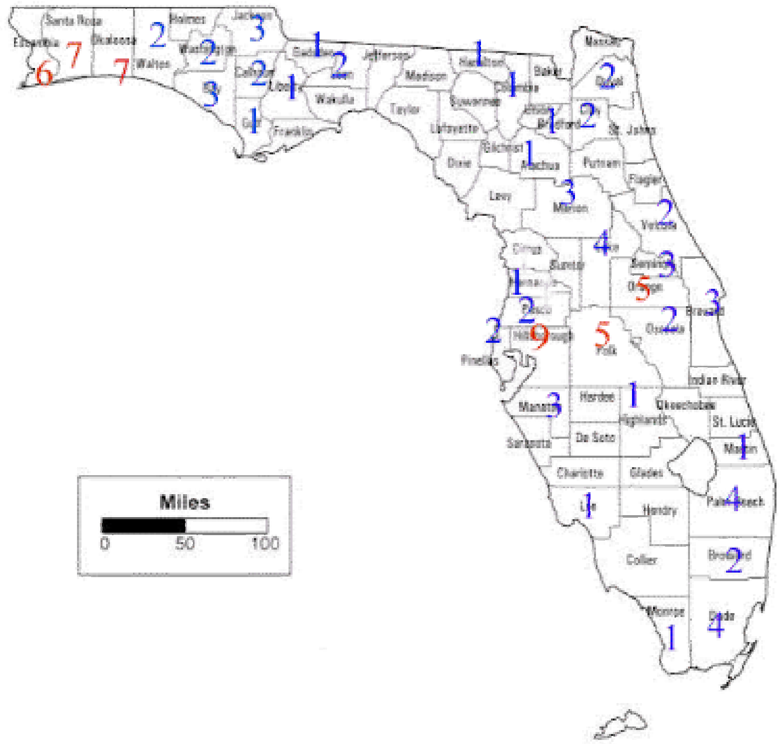
FIG 5. The total number of (a) F1 and greater intensity tornadoes and (b) F2 and greater intensity tornadoes that occurred during all La Niña years in each Florida county.



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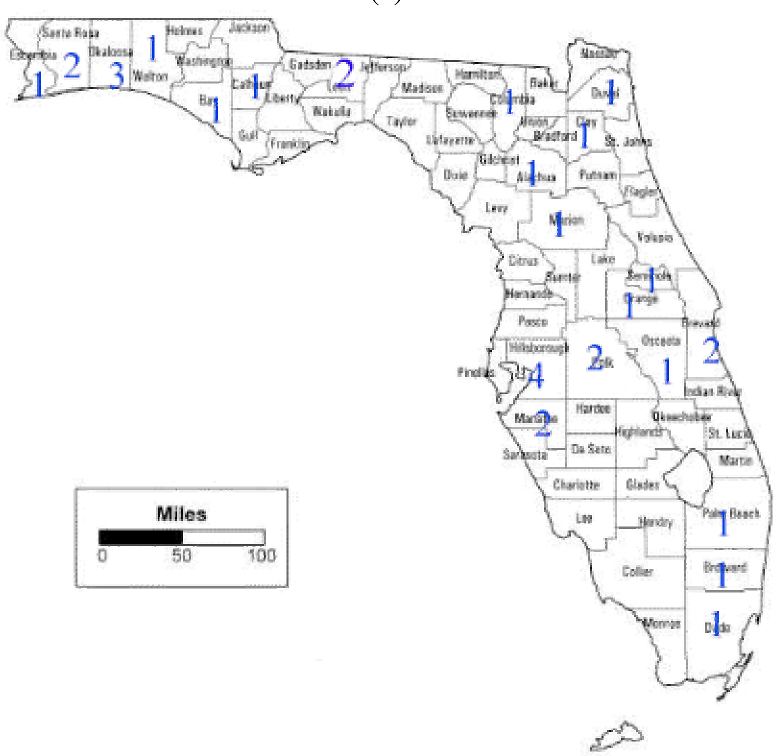

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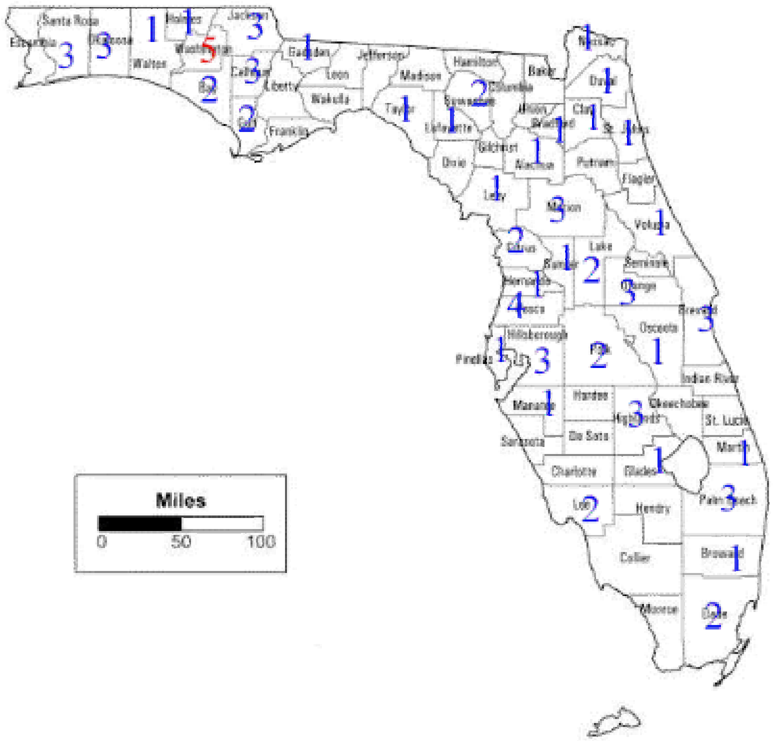
FIG 6. The total number of (a) F1 and greater intensity tornadoes and (b) F2 and greater intensity tornadoes that occurred during all ENSO neutral years in each Florida county.



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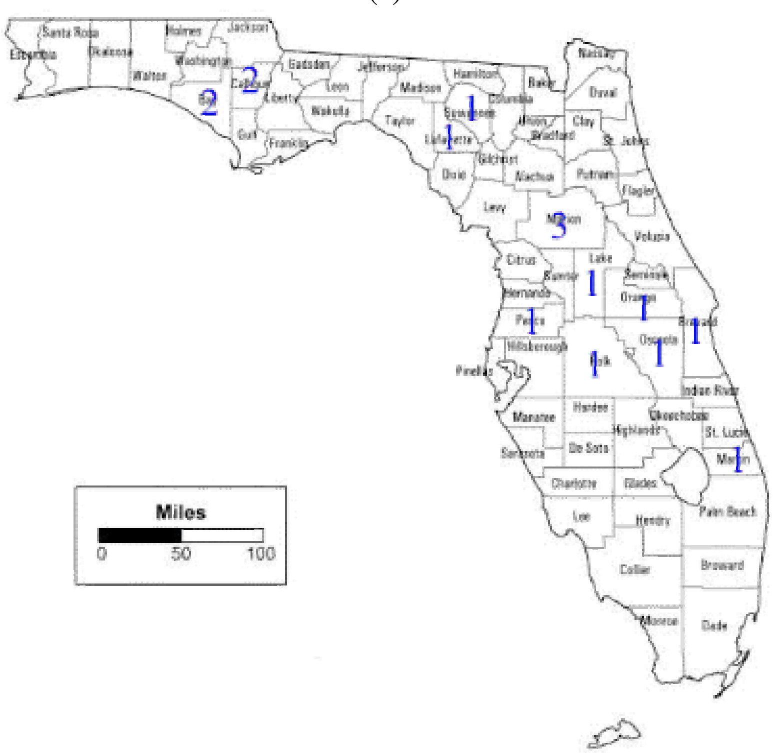

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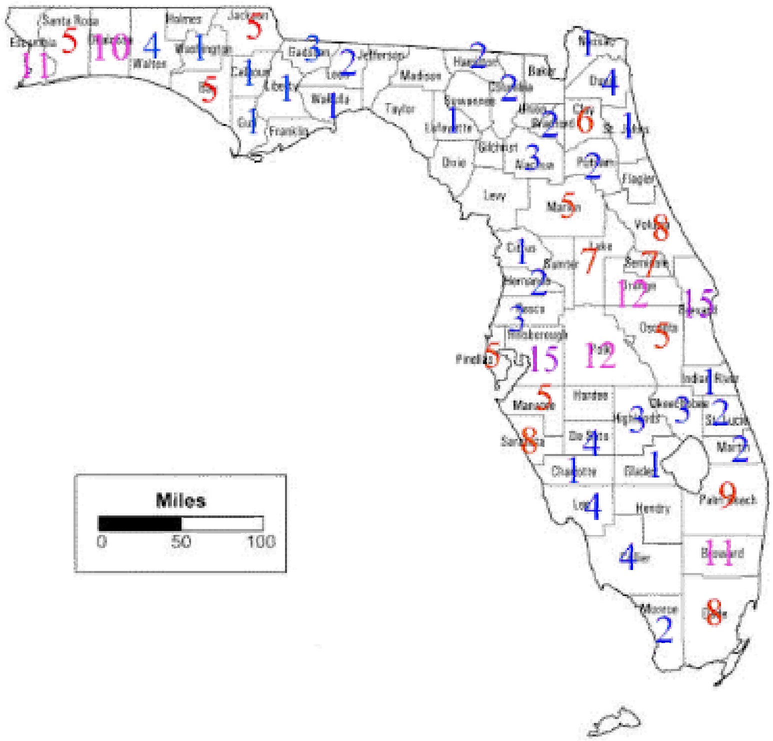
FIG 7. The total number of (a) F1 and greater intensity tornadoes and (b) F2 and greater intensity tornadoes that occurred during all AO positive years in each Florida county.



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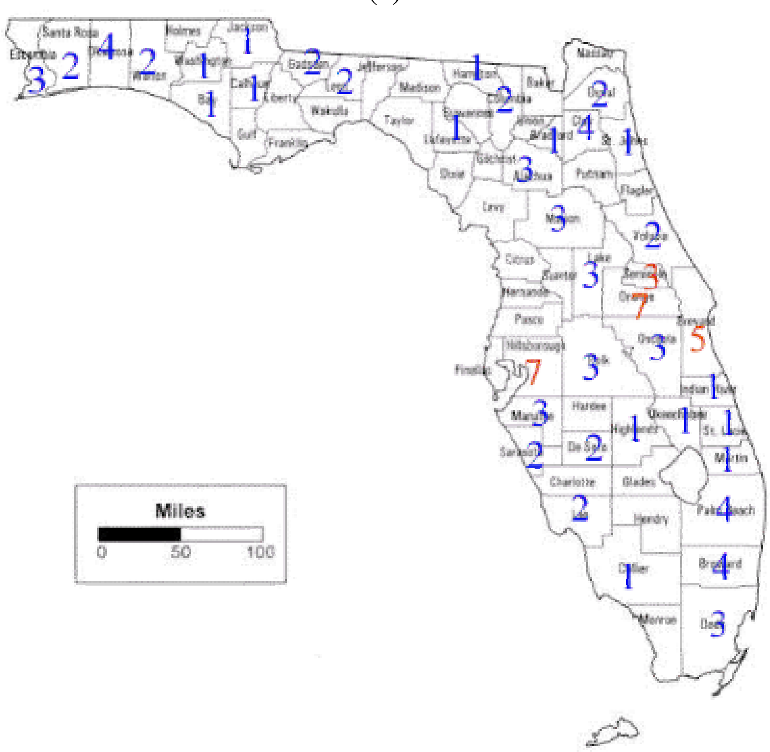
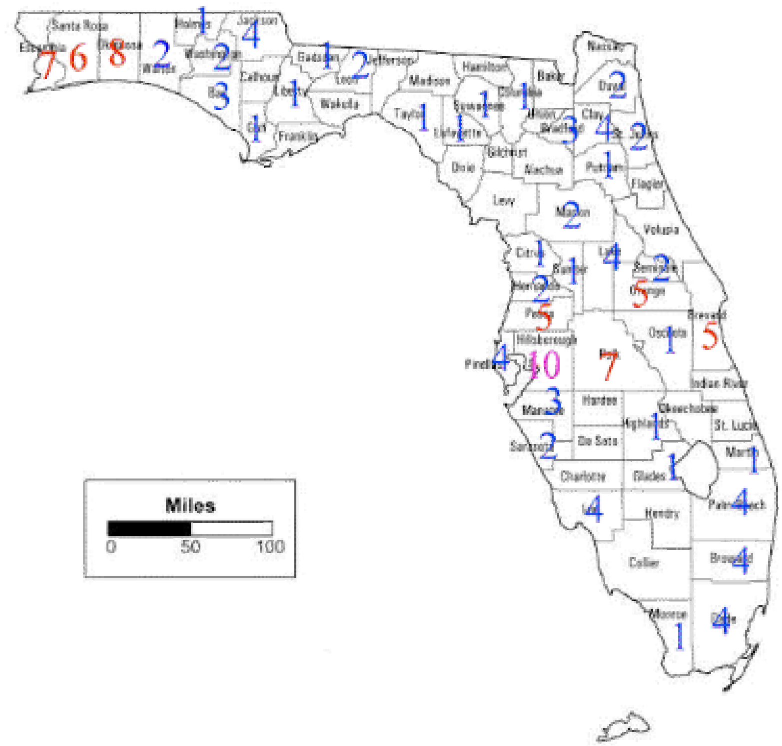


(b)

FIG 8. The total number of (a) F1 and greater intensity tornadoes and (b) F2 and greater intensity tornadoes that occurred during all AO negative years in each Florida county.



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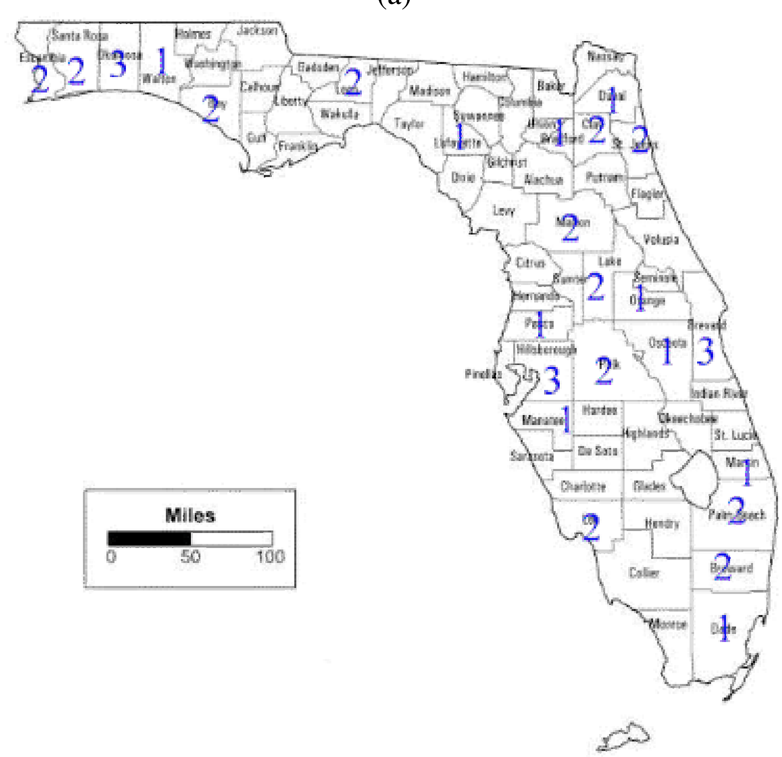
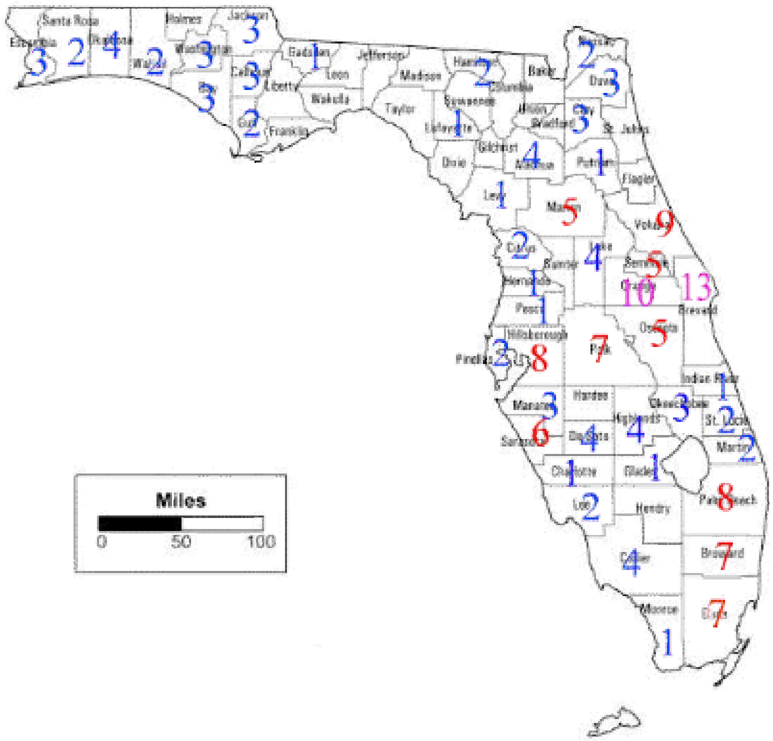


(b)

FIG 9. The total number of (a) F1 and greater intensity tornadoes and (b) F2 and greater intensity tornadoes that occurred during all PDO negative years in each Florida county.



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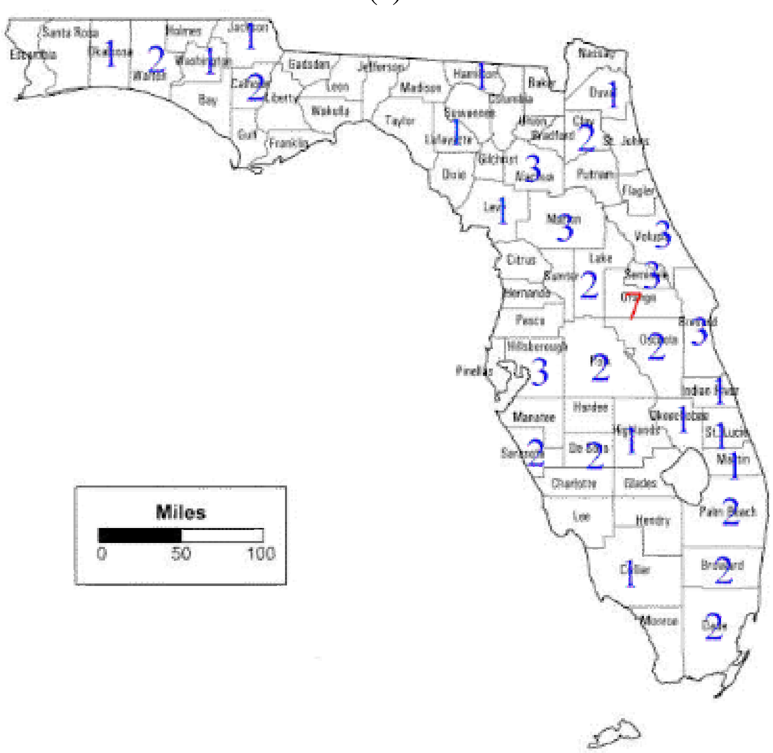

(b)

FIG 10. The total number of (a) F1 and greater intensity tornadoes and (b) F2 and greater intensity tornadoes that occurred during all PDO positive years in each Florida county.

Table 1. The following is a list of El Niño and La Niña episodes by winter season from 1953 – 2002 as defined by the CPC (2003) and associated number of F1 and greater intensity and F2 and greater intensity tornadoes. Moderate warm anomalies are indicated with a "W" and moderate cold anomalies by "C". Strong and weak anomalies are indicated by a (+) or (–) respectively. Neutral seasons are indicated with an "N".

Year	ENSO	F1+	F2+	Year	ENSO	F1+	F2+
1953	N	3	1	1978	W-	11	4
1954	N	1	0	1979	N	5	1
1955	C	0	0	1980	W-	7	1
1956	C	1	1	1981	N	8	3
1957	N	1	1	1982	N	6	0
1958	W+	5	3	1983	W+	29	14
1959	W-	0	0	1984	C-	4	2
1960	N	8	5	1985	C-	5	1
1961	N	3	0	1986	N	8	2
1962	N	7	4	1987	W	0	0
1963	N	3	2	1988	W-	1	0
1964	N	5	1	1989	C+	1	0
1965	C-	5	3	1990	N	1	0
1966	W	0	0	1991	W-	6	0
1967	N	1	0	1992	W+	4	0
1968	N	4	1	1993	W-	8	3
1969	W	1	0	1994	N	0	0
1970	W-	14	8	1995	W	2	1
1971	C	10	6	1996	C-	4	1
1972	N	27	10	1997	N	8	1
1973	W	13	7	1998	W+	32	10
1974	C+	9	2	1999	C+	5	1
1975	C-	22	6	2000	C	4	0
1976	C	0	0	2001	C-	7	6
1977	N	2	0	2002	N	1	0

Table 2. The Fujita scale (F-scale) classification and description. (from Tornado Project Online 2003)

F-Scale Number	Intensity Phrase	Wind Speed	Type of Damage Done
F0	Gale tornado	40-72 mph	Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages sign boards.
F1	Moderate tornado	73-112 mph	The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.
F2	Significant tornado	113-157 mph	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.
F3	Severe tornado	158-206 mph	Roof and some walls torn off well constructed houses; trains overturned; most trees in forest uprooted
F4	Devastating tornado	207-260 mph	Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated.
F5	Incredible tornado	261-318 mph	Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile sized missiles fly through the air in excess of 100 meters; trees debarked; steel reinforced concrete structures badly damaged.

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