Southeastern US Daily Temperature Ranges and Predictability with ENSO

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Abstract

The diurnal temperature ranges (DTRs) in the Southeastern United States have a wide distribution of magnitudes, and patterns in this distribution are witnessed on both spatial and temporal scales. Rapid or intense changes in daily temperatures can create heat/cold stress on animals or tax a power grid; therefore an accurate prediction of these climate-driven fluctuations will be helpful for the equestrian, cattle, and energy industries. It is hypothesized that in addition to seasonal and annual distributions, DTRs also vary with respect to the climatological phase of the El Niño Southern Oscillation (ENSO). It is well documented that ENSO has impacts on temperatures in the Southeast US, especially in the winter months. A 62-year record of quality-controlled observations collected from the National Weather Service's Cooperative Observing Network (COOP) is being used for analysis. Probability distribution functions (PDFs) will be applied to show that DTRs vary in response to El Niño or La Niña with statistical significance. These varied responses will be shown both temporally and spatially across the region. Results will show that DTRs are extreme with a higher probability during the La Niña phase compared to the mean, particularly during seasonal transitions. The converse is true for the El Niño phase. These results allow seasonal predictability of the extreme DTR events depending upon the current (or expected) phase of ENSO.

Motivation

The Southeastern United States is well known for its cattle and equine industries, particularly in central Florida. Previous studies (Fuquay 1981, Ishii et al. 2001) indicate that temperatures play a vital role in induced heat/thermal stress on these animals. The El Nino Southern Oscillation has documented effects on Southeastern U.S. climate conditions. It is hypothesized that extreme daily temperature ranges may produce greater heat stress on cattle/horses, and the likelihood of these extreme events may be ENSO-phase dependant.

Data & Methodology

- Temperature maximums and minimums drawn from the National Weather Service's Cooperative Observing Network (COOP) , NCDC's DS3200/6, including five southeastern states (NCDC 2008). This data is quality-controlled and missing values were replaced with a documented method using surrounding stations with multiple linear regression (Smith 2006).

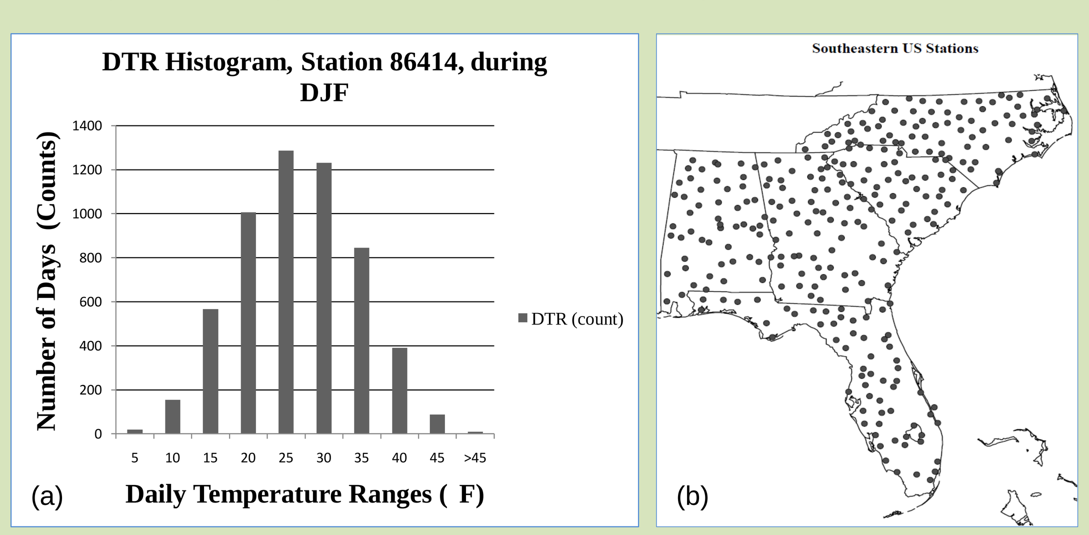


Figure 1: (a) The DTR histogram for Ocala (with noticeably normal distribution) and (b) spatial plot of all stations used in this study.

- The 62-year period of 1948-2009; data existed for all 292 stations over the majority of the temporal domain.
- ENSO data drawn from a modified Japan Meteorology Agency (JMA) Index with phases specified by month.

Study Characteristics:

- The Diurnal Temperature Range (DTR) = Tmax–Tmin.
- Bins labeled with DTRs represent the range from that value to 5 degrees Fahrenheit less; i.e. the counts in the 15 bin have a 10-15° Fahrenheit DTR.
- Months and their DTRs are categorized by the corresponding ENSO phase.

Case Study: Ocala

- Cumulative Probability Distribution Functions (PDFs) were created with cumulative binning and division by the total count in each phase (El Niño, Neutral, or La Niña). They represent the probability of *reaching* a specific DTR. All plots in degrees Fahrenheit.
- Although the methods described applied to 292 stations, for brevity the distributions and PDFs for Ocala are presented. Ocala was chosen because it is at the heart of Floridian agriculture and animal husbandry, where the motivation for this study is derived.

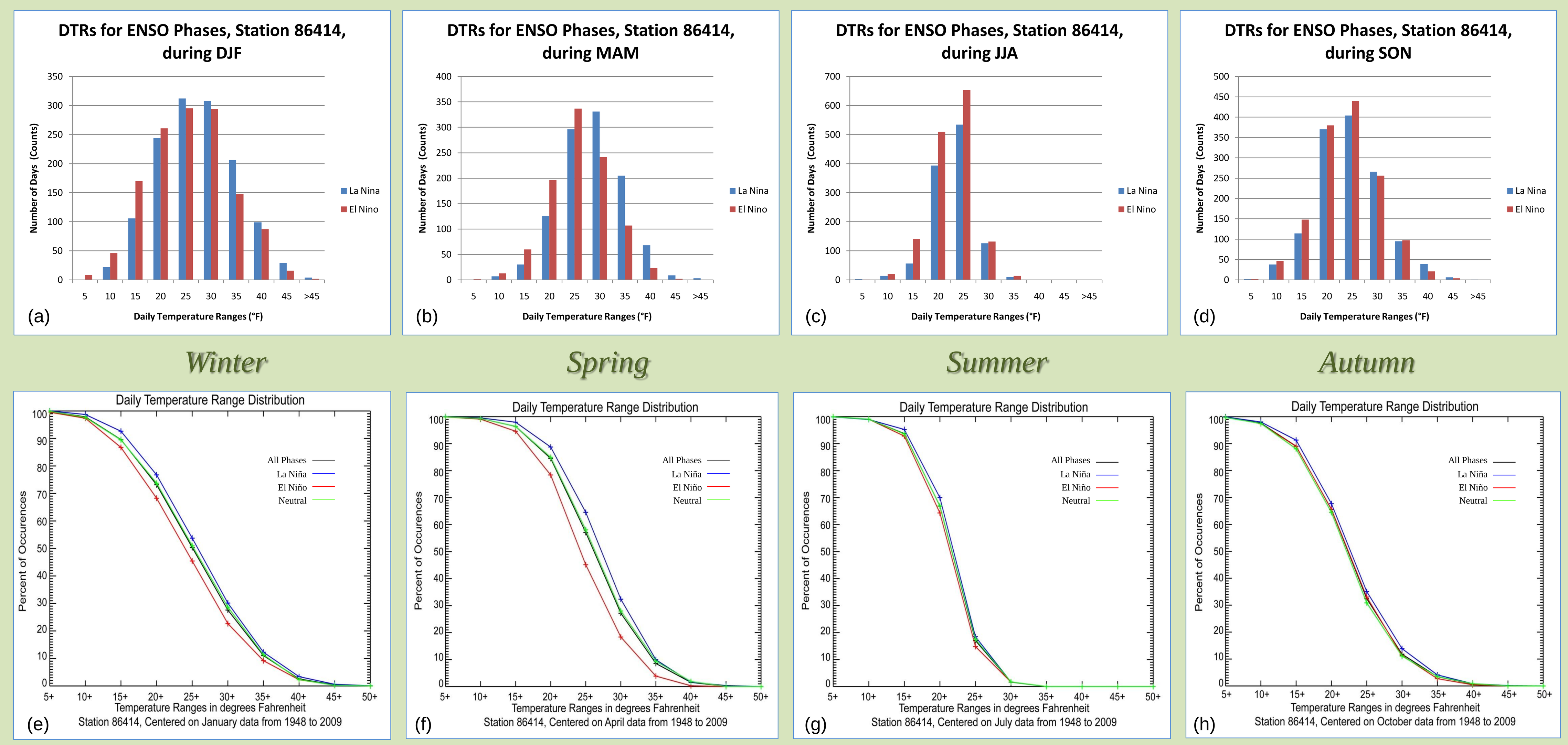
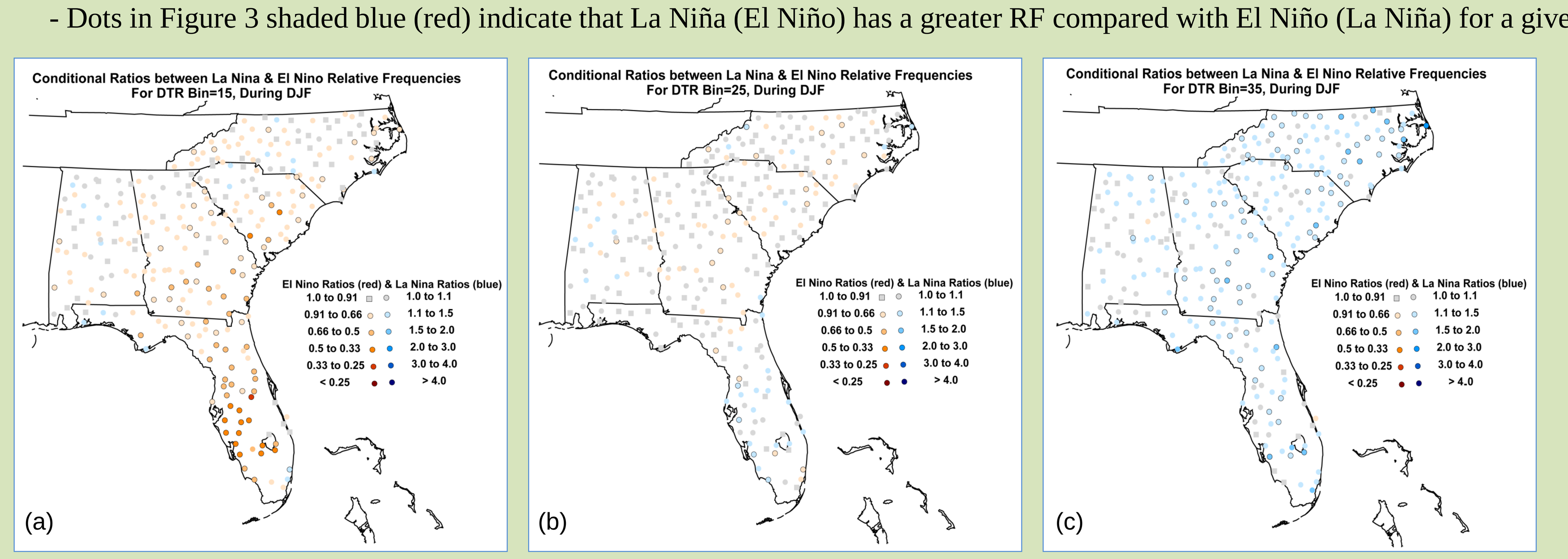


Figure 2: The above plots (a-h) depict both the DTR distributions and cumulative probability distributions for El Niño and La Niña during each season of the year. It is clear that the distribution for La Niña is shifted towards higher DTRs in the winter and spring; conversely it is shifted towards lower DTRs during El Niño for those months. There is little consistency in summer and autumn plots, with a leaning towards a greater total El Niño signal. The cumulative PDFs similarly show that the probability of reaching a higher DTR is 10%-20% greater during La Niña than during El Niño during winter and spring, while there is little difference in the summer and autumn plots. Because of this, further investigation focuses on winter and spring.

Spatial Differences

- The Conditional Ratios (CRs) show the ratio between the Relative Frequencies (RFs) of counts in DTR bins between La Niña and El Niño.
- Dots in Figure 3 shaded blue (red) indicate that La Niña (El Niño) has a greater RF compared with El Niño (La Niña) for a given season and bin.



Winter

For example (35° Fahrenheit DTR):

$$\text{Relative Frequency} = \frac{\#\text{ of counts in 35 bin}}{\#\text{ of counts in all bins}}$$

Then we calculate:

$$\text{Conditonal Ratio} = \frac{\text{Relative Frequency for La Niña}}{\text{Relative Frequency for El Niño}}$$

Spring

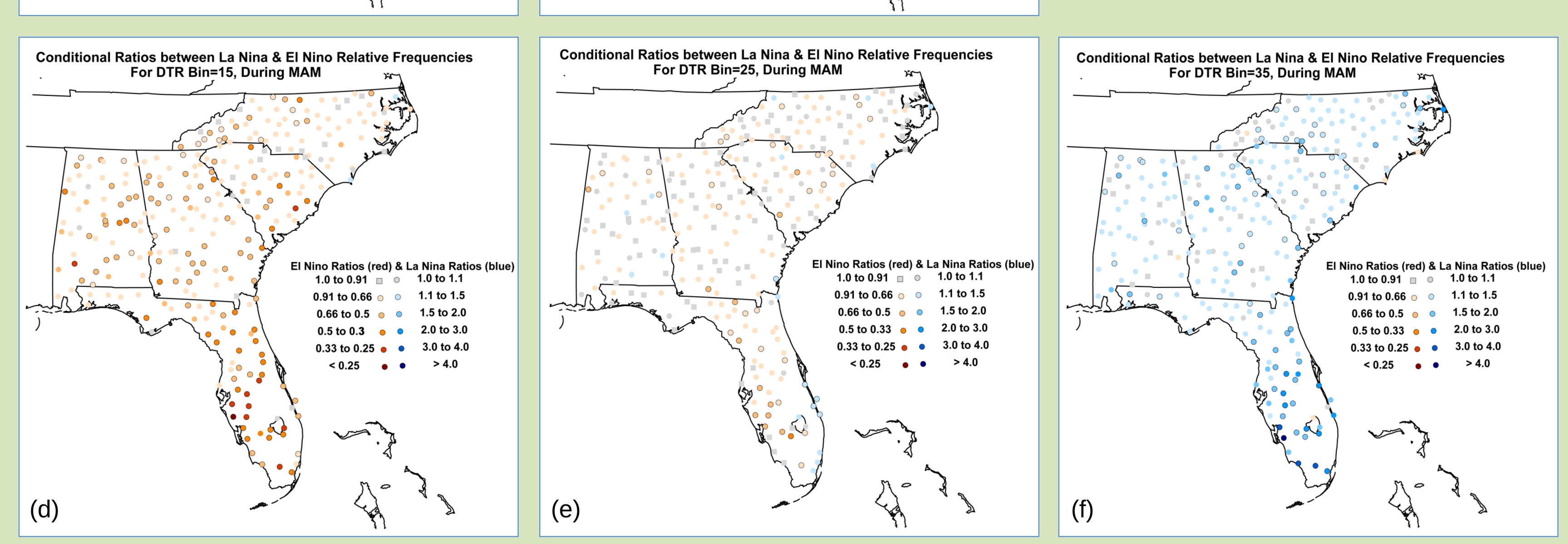


Figure 3: The above plots (a-f) depict the Conditional Ratios for the Southeast US (with DTRs in degrees Fahrenheit). Significant CRs are outlined in black. Spring generally is twice as likely to have significant differences from unity (1.0) than winter. In Florida, this increase is multiple is even greater (as much as 4 times as likely) at various stations. During spring the 15 bin has the strongest significant differences from unity w.r.t. El Niño across every Southeast state. Similarly, during spring the 35 bin has strong significant differences from unity w.r.t. La Niña. Each of the 15 and 35 bins have significant differences in FL, especially central and southwest FL. The 25 bin has little significance in any state, with an exception of these FL regions, where there is a shift from significance w.r.t. La Niña in winter to significance w.r.t. El Niño in spring. El Niño dominates significant ratios at low DTRs (15 bin). La Niña dominates significant ratios at high DTRs (35 bin).

Significance Testing

Bootstrapping technique applied to the data

- 1000 "simulated climates" drawn from 62 years of ENSO data with replacement
- The observed conditional ratios are compared with the simulated conditional ratios
- The significance test determines whether the Conditional Ratios are significantly different from unity (1.0) at 95% confidence
- Values are significant with respect to La Niña (>1.0) or El Niño (<1.0)
- Table 1, below, shows the significant station counts (out of 292) for each bin by phase and season:

	DTR Bins (°F)	5	10	15	20	25	30	35	40	45	50
Spring	w.r.t. La Niña	0	0	0	0	5	48	71	66	16	0
	w.r.t. El Niño	0	97	121	95	41	1	2	28	55	22
Winter	w.r.t. La Niña	0	0	1	1	6	33	76	56	21	0
	w.r.t. El Niño	60	112	80	57	19	3	0	8	28	17

Table 1: The number of stations (of 292) with ratios significant from unity per bin, phase, and season

Discussion

- *Ocala* was significantly different from unity in the 15 bin (w.r.t. El Niño) and 35 bin (w.r.t. La Niña) during both winter and spring.
- The spring 15 bin has 41% more stations significantly different from unity w.r.t. El Niño than w.r.t. La Niña. The winter 15 bin has 27% more stations significantly different from unity w.r.t. El Niño than w.r.t. La Niña.
- The spring 35 bin has 23% more stations significantly different from unity w.r.t. La Niña than w.r.t. El Niño. The winter 35 bin has 26% more stations significantly different from unity w.r.t. La Niña than w.r.t. El Niño.
- 30% of all calculated spring station bins are significantly different from unity, while 24% of all calculated winter station bins are significantly different from unity.
- Significance for El Niño shifts from higher DTR bins (10,15, 20) in spring to lower DTR bins (5, 10, 15) in winter. La Niña significance does not noticeably shift between seasons.

Conclusions & Future Work

- DTRs are normally distributed in the Southeastern US.
- During the winter and spring months for many stations: the distribution of DTRs during El Niño is shifted towards lower ranges, while the distribution of DTRs during La Niña is shifted towards higher ranges. This is generally not reflected during summer or autumn.
- During the winter and spring months: the *probability of high DTRs* is **10% to 20% greater** for **La Niña**; the *probability of low DTRs* is **10% to 20% greater** for **El Niño**.
- The CRs show: *during a La Niña **higher** DTRs are significantly 2-4 times more common than during El Niño*, in winter and spring. Conversely, *during an El Niño **lower** DTRs are significantly 2-4 times more common than during La Niña*, in winter and spring.
- This signal is represented strongly in central Florida and is generally at least twice as large as surrounding significant differences. Spring ratios are generally also twice as large as winter ratios.

These results indicate that prediction of extreme (low or high) DTRs based on ENSO phase is possible, but further work must be conducted. In future studies, a physical explanation (such as moisture or urban effects) for these DTR shifts during different ENSO phases must be sought. Possible connections with the AMO or NAO should be explored, especially regionally. Additionally, applying specific heat indices to cattle/horses and correlating these with ENSO is vital to understanding the full impact on those industries.

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