Characteristics of ENSO-Associated Southeast US Daily Temperature Range Frequencies

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Introduction

Daily temperature ranges (DTRs) in the Southeast United States have a wide distribution of magnitudes; patterns in this distribution are observed 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 could be helpful for agricultural, livestock, and energy industries. It is hypothesized that in addition to seasonal and annual distributions, DTR frequencies vary with respect to the climatological phase of El Niño-Southern Oscillation (ENSO). It is well documented that ENSO has climate impacts in the Southeast US (e.g., Ropelewski and Halpert 1986). El Niño phase is typically associated with warm and wet winters whereas La Niña phase is typically associated with cool and dry winters. Maximum and minimum temperatures (Lim and Schubert 2011) and extreme mean temperatures (Gershunov and Barnett 1998, Higgins et al. 2001) are known to be specifically influenced by ENSO in the winter. Monthly averaged DTRs have been shown to vary in the winter with respect to ENSO (Mote 1996). The purpose of this study is to determine the relationship between high-resolution daily DTRs and ENSO and make the information available to stakeholders for application purposes. A 62-year record of quality-controlled observations collected from 290 stations of the National Weather Service's Cooperative Observing Network is used for analysis. Histograms are created to evaluate the distributions (all-year and ENSO-separated) for the 290 stations and all four seasons. To make the analysis manageable, the authors develop a new metric, identified as conditional ratios in this study. These conditional ratios enable us to directly compare ENSO phases and perform spatial and statistical analyses. A tool more relevant to stakeholders, exceedance probability graphs, is created. Results show that high DTRs are significantly associated with La Niña events whereas low DTRs are significantly associated with El Niño events. The response is stronger during spring than winter.

Data

- NCDC's DS3200 digital database (NCDC 2008)
  - Minimum and maximum temperatures (T_{min} and T_{max})
  - 290 Southeast stations (Fig. 1b) from the Cooperative Observing Network
  - Quality-controlled; missing values replaced with a multiple linear regression technique (Smith 2007)
  - 229 stations have a temporal domain of 1948-2009, 62 years
  - Remaining 61 stations have records of 35 to 61 years
  - ENSO defined with a monthly Japan Meteorological Agency (JMA) Index

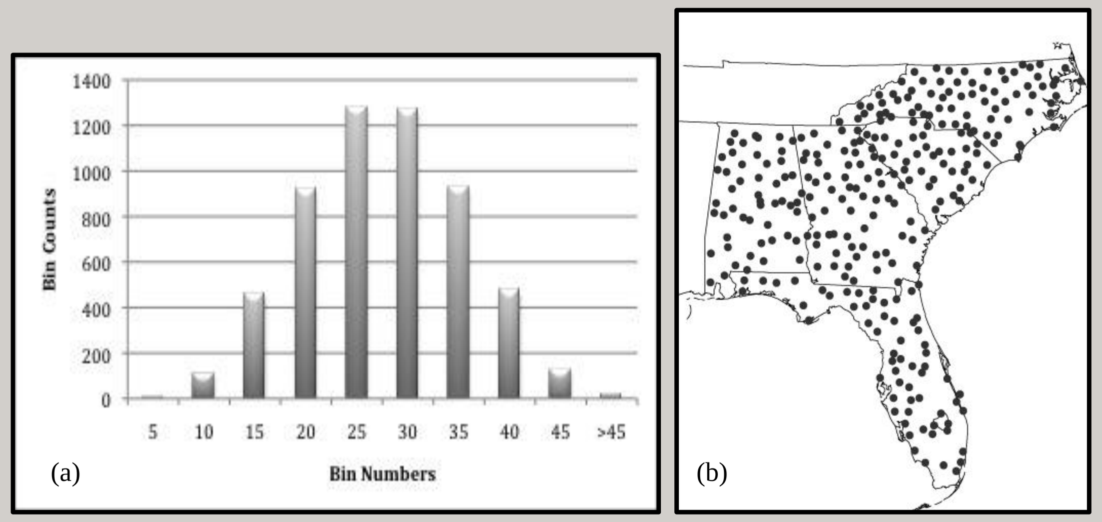

Figure 1: (a) The all-year DTR histogram for Ocala, Florida (with a normal distribution) and (b) spatial plot of 290 Southeast stations used in this study.

- Study Characteristics
  - For a given day, τ, the Daily Temperature Range (DTR) is defined as

$$DTR(\tau) = \left[Tmax(\tau) - Tmin(\tau)\right] \quad \text{(Equation 1).}$$

  - Distributions of DTR values are generally Gaussian (Fig. 1a).
  - Bins are labeled in 5°F increments representing the 5° range directly below them (e.g., Bin Number 15 contains DTR counts of [10-14°F]).
  - Seasons are March, April, May (MAM), June, July, August (JJA) and September, October, November (SON), December, January, February (DJF).

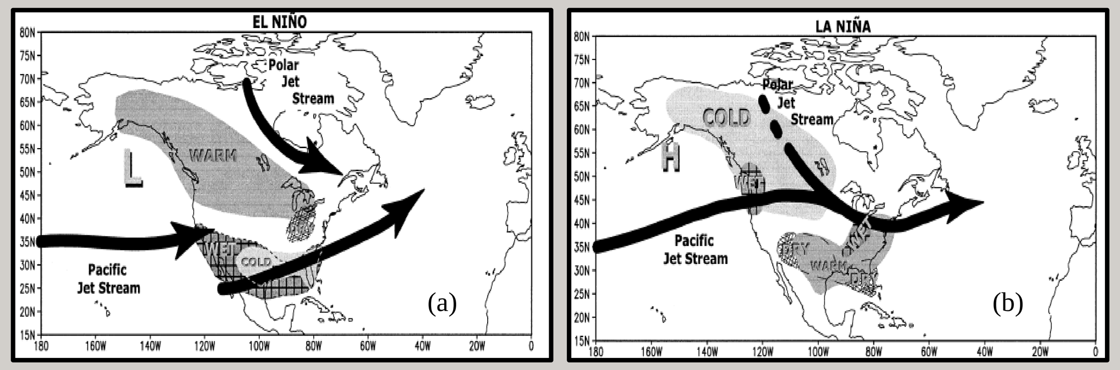

Figure 2a-b: Composite climate conditions in North America during (a) El Niño and (b) La Niña events (Higgins et al. 2002).

Distributions: Ocala, Florida Case Study

Marion County, Florida, ranks number 1 out of 3066 reporting US counties in horse and pony inventories and number 3 out of 3024 reporting US counties in equine sale value (USDA 2007). The Ocala station, in central Marion county, is chosen as a case study (Fig. 3) to reflect the range of DTRs in this robust equine development area and because results for this station are fairly typical of ENSO-separated DTR distributions in the Southeast.

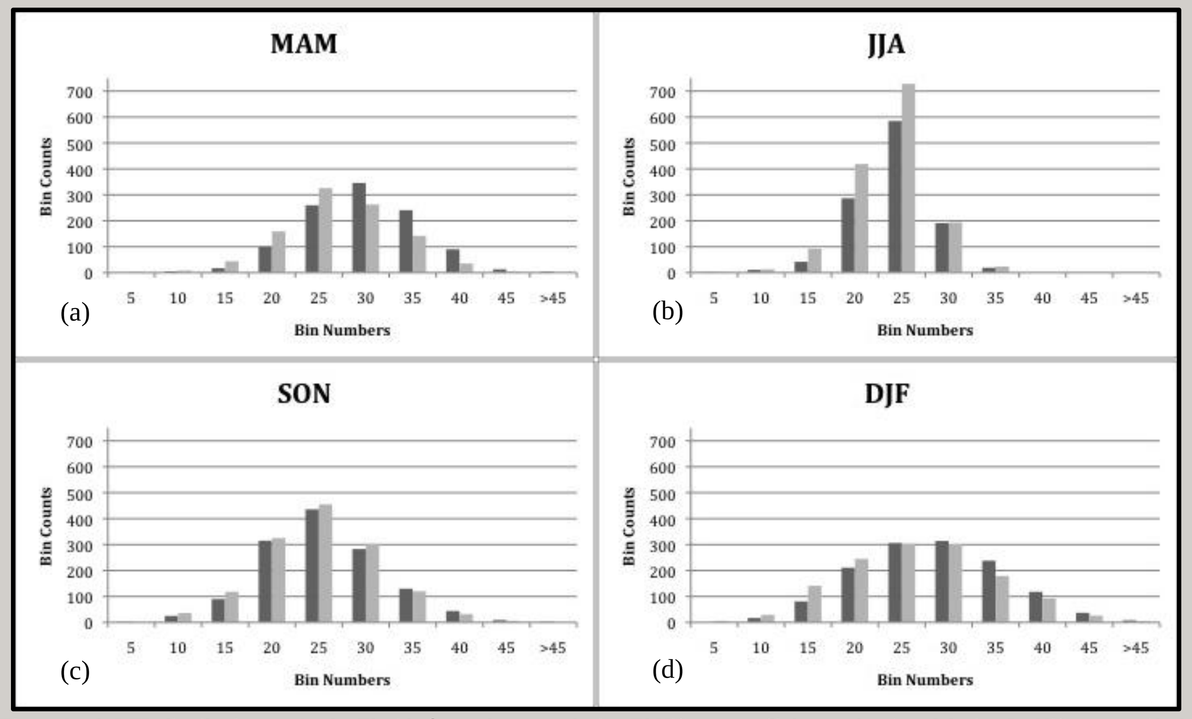

Figure 3a-d: DTR distributions at Ocala, Florida for each season during El Niño events (light grey bars) and during La Niña events (dark grey bars).

- **The majority of the JJA distribution is gathered between bin numbers 15 and 35, with no consistent variability.**
- **El Niño (La Niña) distributions are "shifted" toward lower (higher) DTRs in MAM, SON, and DJF.**
- **The counts, primarily in bin number 15 (bin number 35), are greater for El Niño's (La Niña's) distribution than La Niña's (El Niño's) distribution.**
- **Bin numbers 25 and 30 are the median bins for the distributions.**
- **The greatest difference of counts between the ENSO phases occurs in MAM; the least difference (disregarding JJA) occurs in SON.**
- **We hypothesize that higher DTRs occur more often during La Niña; lower DTRs occur more often during El Niño.**

Statistical & Spatial Analysis

- The *conditional ratio* (CR) is developed to investigate the hypothesis on a large scale.
  - At each station, counts for a given ENSO phase (ϕ) in each bin are normalized by the counts in all bins, and called the *relative frequency* (RF, Eq. 2).
  - A balanced ratio between the ENSO phase RFs yields a CR value of 1.0 (unity).
  - CR values above unity (below unity) will have greater La Niña (El Niño) RFs than El Niño (La Niña) RFs (Eq. 3).
  - CRs for a given season (S) and bin number (j) are calculated for each station.
  - A large (small) magnitude CR can be indicative of either a high La Niña (El Niño) RF, a low El Niño (La Niña) RF, or some combination of these conditions.
- Bootstrapping is applied to assess the significance of CRs (Efron and Gong 1983).
  - A nonparametric approach is used to sample with replacement and construct a 1,000-member ensemble.
  - Distributions are tested to determine if a CR is significantly different from unity at 95% confidence.
  - CRs significantly above (below) unity have a La Niña (El Niño) RF that is significantly greater than the corresponding El Niño (La Niña) RF.

$$RF(j,S,\phi) = \left[\frac{Counts(j,S,\phi)}{Counts(\forall j,S,\phi)}\right] \quad \text{(Equation 2)}$$

$$CR(j,S) = \left[\frac{RF(j,S,La\ Nina)}{RF(j,S,El\ Nino)}\right] \quad \text{(Equation 3)}$$

- **Unity plots**
  - **Bin number 15 (35) has many stations significantly below (above) unity.**
  - **Bin number 25 has few significant results; there is small tendency toward significance below unity.**
  - **In bin number 15, magnitude and number of significant CRs is stronger during MAM than DJF.**
  - **In bin number 35, magnitude of CRs is greater during MAM than during DJF, while the number of significant CRs is nearly equal for both seasons.**
- **Plan-view maps**
  - **The strongest magnitude and most number of significant CRs are in southwest and central Florida.**
  - **Bin number 15 during MAM has the smallest magnitude CRs and the broadest/most significant patterns.**
  - **Significance is shifted farther south in DJF than in MAM.**
  - **Bin number 35 during MAM has the largest magnitude CRs.**

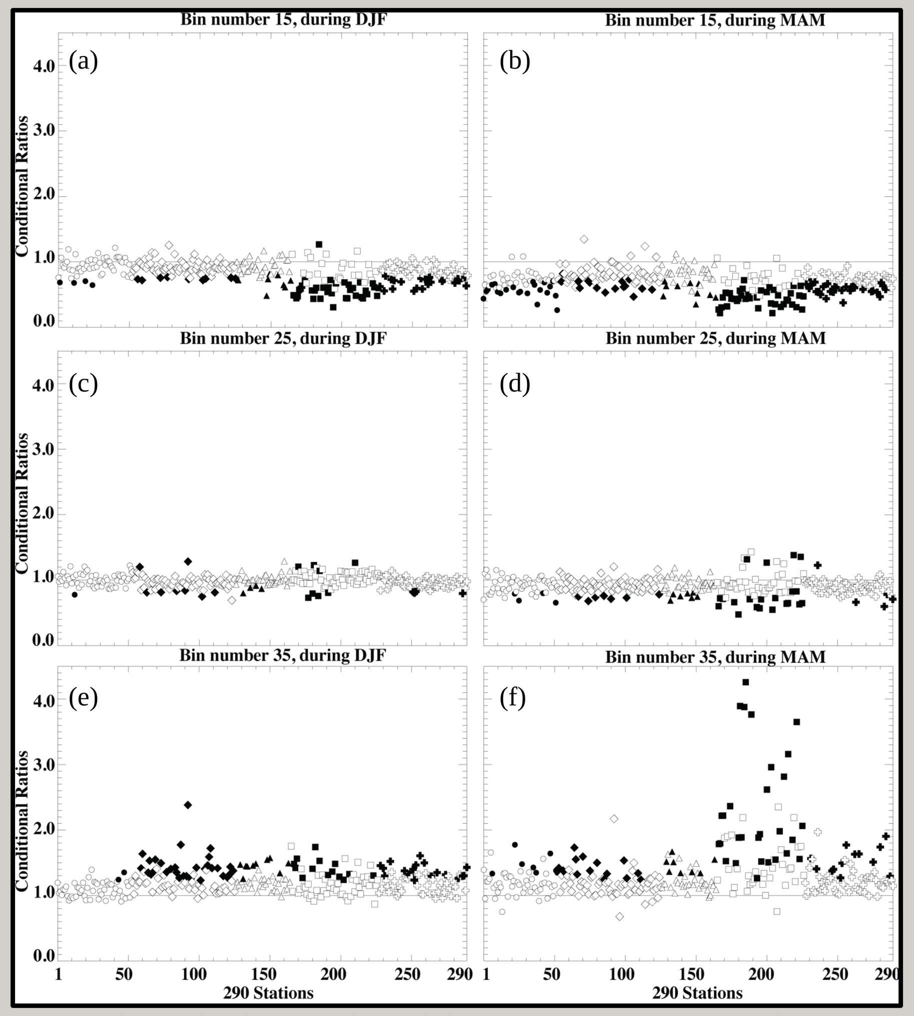

Figure 4a-f: Unity plots show CRs with symbols dependant on state: circle (Alabama), diamond (North Carolina), triangle (South Carolina), square (Florida), and cross (Georgia). Significant CRs are filled in black.

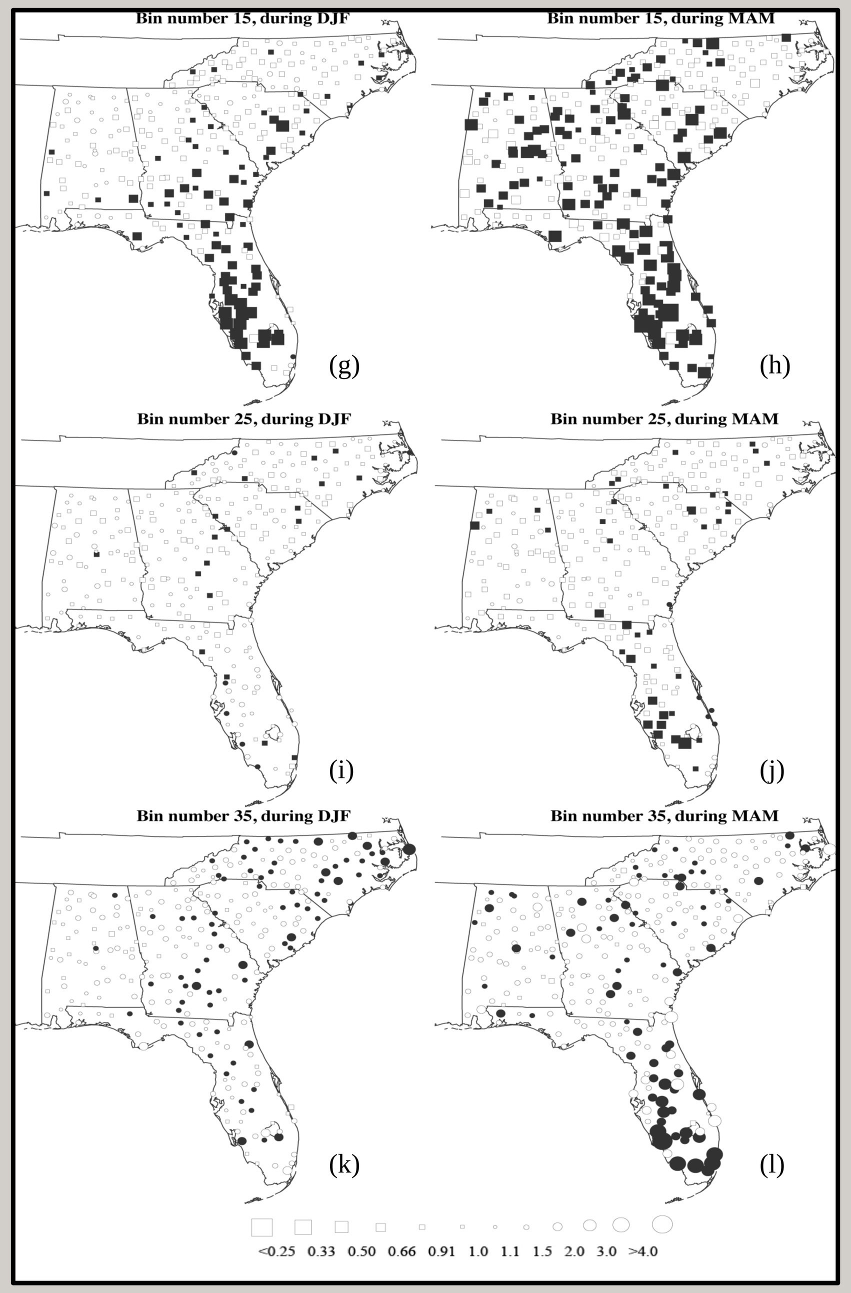

Figure 5g-l: Plan-view maps depict CRs above unity (circles) and below unity (squares). Significant CRs are filled in black.

	DTR Bins (°F)	5	10	15	20	25	30	35	40	45	>45
MAM	Above Unity	0	0	0	0	5	48	71	74	19	5
	Below Unity	0	74	119	93	39	0	0	0	0	0
DJF	Above Unity	0	0	1	1	6	33	76	56	20	5
	Below Unity	12	109	79	56	19	2	0	0	1	0

Table 1: The number of stations with CRs significantly different from unity is shown in each column, separated by bin, season, and ENSO phase. "Above unity" rows have stations with significant CRs that have larger La Niña RFs. "Below unity" rows have stations with significant CRs that have larger El Niño RFs.

A Tool for the Stakeholder

- *Exceedance probabilities* provide a graphical tool that is intuitive for stakeholders.
  - An exceedance probability evaluates the historical probability of *reaching* a particular DTR value on any given day during a specific season and ENSO phase.
  - For each station, exceedance probabilities are calculated for each bin (j), season (S), and ENSO phase (ϕ).

$$Probability(j,S,\phi) = \left[\frac{\sum_{i=j}^{Bin\ Number>45} Counts(i,S,\phi)}{Counts(\forall j,S,\phi)}\right] \quad \text{(Equation 4)}$$

  - The exceedance probability graph for Ocala is an example of typical Southeast results (Fig. 6).

- **La Niña exceedance probabilities are higher than those of El Niño during MAM and DJF in every bin.**
- **Bin numbers 20, 25, 30, and 35 have the most notable differences.**
- **The probability of reaching a high DTR is greater during La Niña than during El Niño.**
- **There are no notable differences between ENSO phases for SON and JJA.**

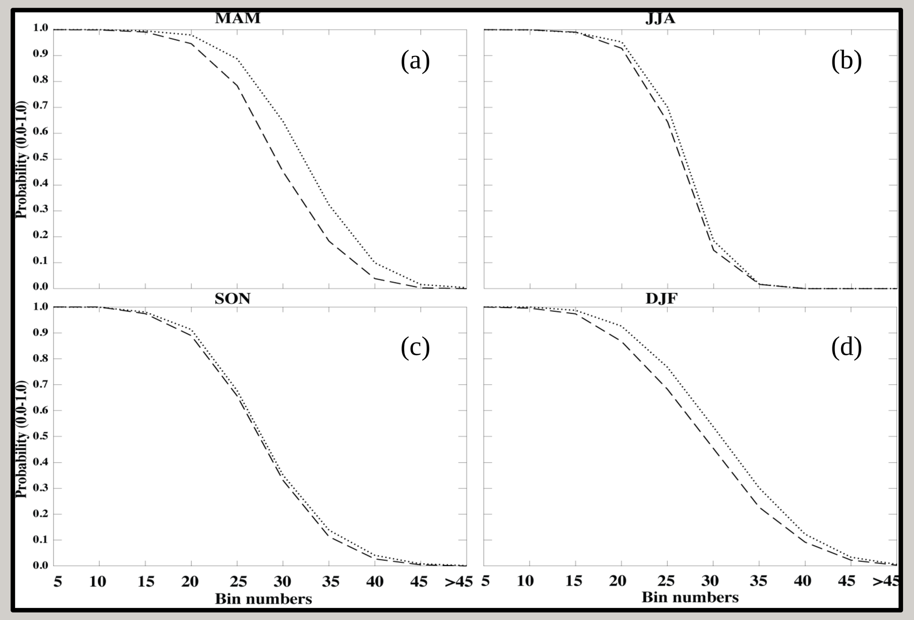

Figure 6a-d: Exceedance probabilities at Ocala, Florida, for each of the four seasons during El Niño events (dashed lines) and La Niña events (dotted lines).

Conclusions & Future Work

- During MAM, DJF, and SON, the distribution of DTRs during El Niño is shifted toward lower ranges, and the distribution of DTRs during La Niña is shifted toward higher ranges. DTRs during JJA do not have significant shifts.
- CRs are significantly different from unity throughout the Southeast, particularly in central and southwest Florida.
- During MAM and DJF CRs in bin number 15 (35) are commonly significant below (above) unity with values between 0.25 and 0.50 (2.0 and 4.0).
- CRs during MAM generally have 1.5-2.0 times greater magnitudes than CRs during DJF. SON CRs have weak magnitudes with some significance. JJA CRs have no significance.
- The probability of reaching any particular DTR in the Southeast is generally larger during a La Niña event than during an El Niño event.
- The probability of reaching a DTR value of 20 or more is generally 10-20% more likely during La Niña than during El Niño in MAM and DJF.

These results indicate that prediction of low or high DTRs based on ENSO phase is possible, and threat mitigation can be conducted if the phase of ENSO is known. It is hypothesized that the relationship between DTRs and ENSO can physically be explained by radiation and synoptic patterns. In the future connections with the AO/NAO/AMO and other known climate drivers should be explored.

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