Extreme Temperature Regimes during the Cool Season: Recent Observed Behavior and Low Frequency Modulation

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General Research Approach & Datasets

- ♠ *Identify extreme temperature regimes (ETRs) in terms of regional anomalies in surface air temperature or wind chill index (Walsh et al 2001; Osczevski and Bluestein 2005)*

  WCI = F (surface air temperature, wind speed)

- ♥ *Basic data: Daily averaged reanalysis data*

  NCEP/NCAR Reanalyses (1949 – 2010)

  (Kalnay et al 1996; used for statistical analyses)

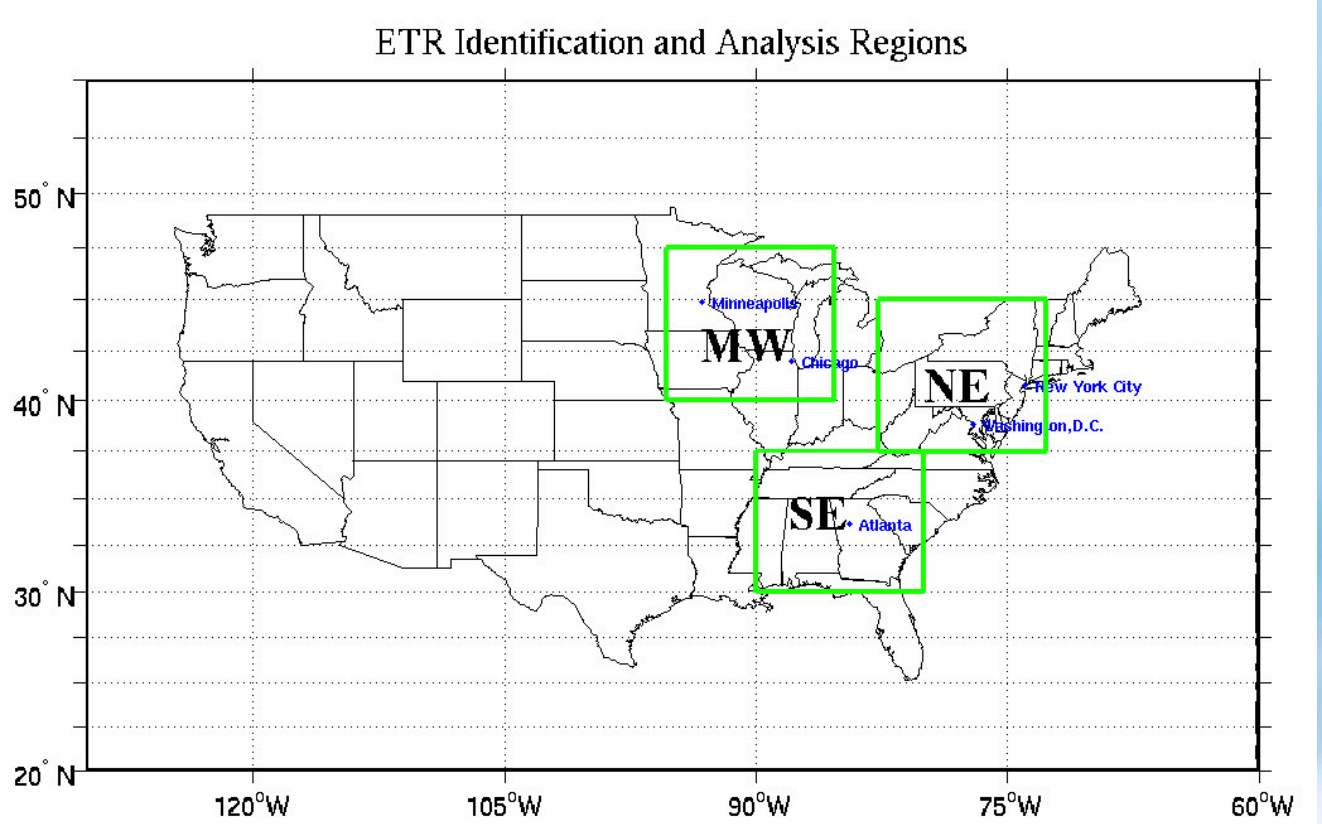
  NASA-GMAO MERRA (1979 – 2010)

  (Bosilovich 2008; used for synoptic-dynamic analyses)

- ♣ *Anomalies defined as normalized departures of either air temperature or wind chill index from daily normal during the months of December, January & February*

Research Approach: Regional Metrics

- ***For each day of the cool season, we construct the areal average of surface air temperature and wind chill index over the following regions (MW, NE, SE):***



Research Approach: Regional Metrics

♠ *Areal average metrics are then used to identify discrete episodes of anomalous temperature/WCI*

1) **Number of days**: *N = # days temperature anomaly is: above +nσ (warm events) or below –nσ (cold events) where n = 1, 1.5 or 2*

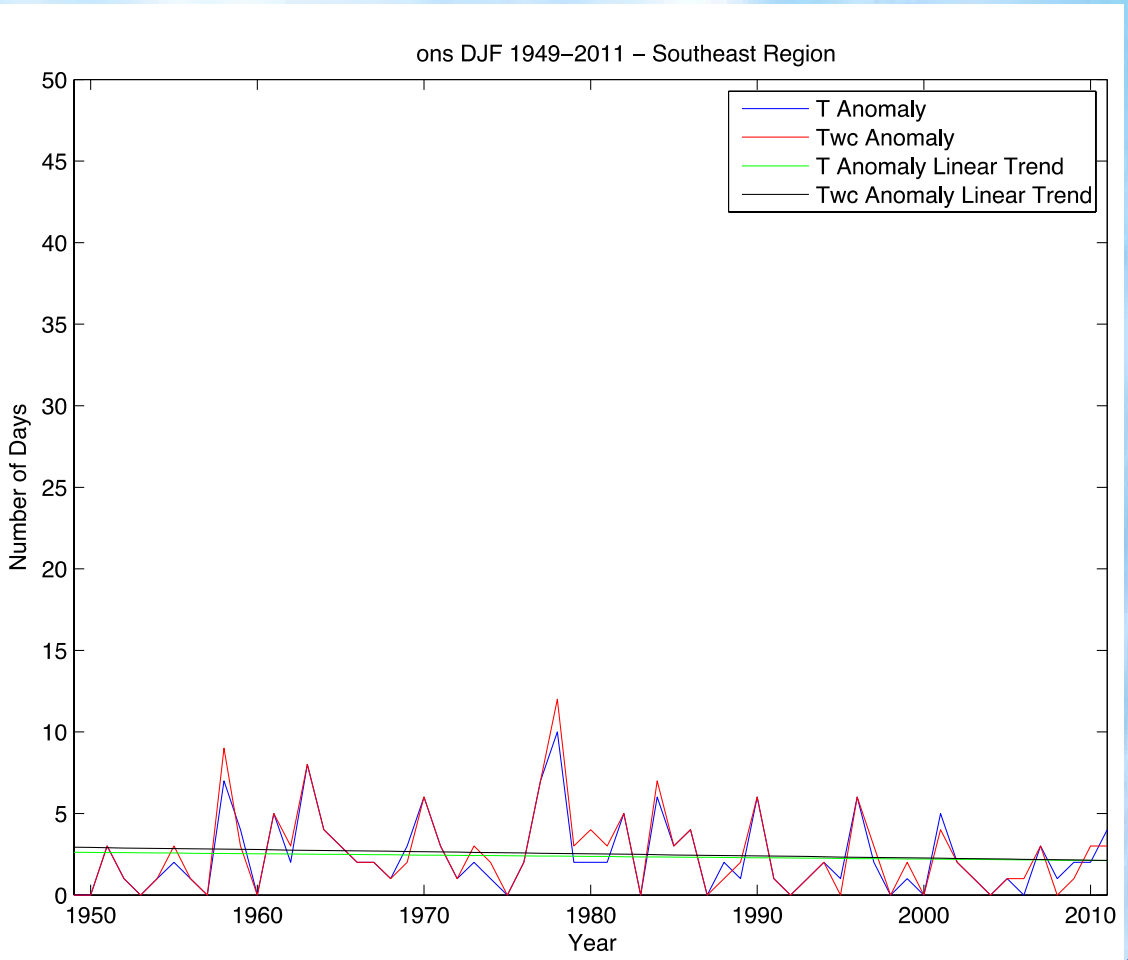
2) **Impact Factor**: *Sum normalized anomaly values for all days exceeding threshold value during each winter.*

$$\text{Impact Factor} = \sum_{i=1}^{N} \left(\frac{T_i'}{\sigma_i} \right)$$

3) **Peak Amplitude**: *Assess largest magnitude (normalized anomaly) warm and cold event for each winter*

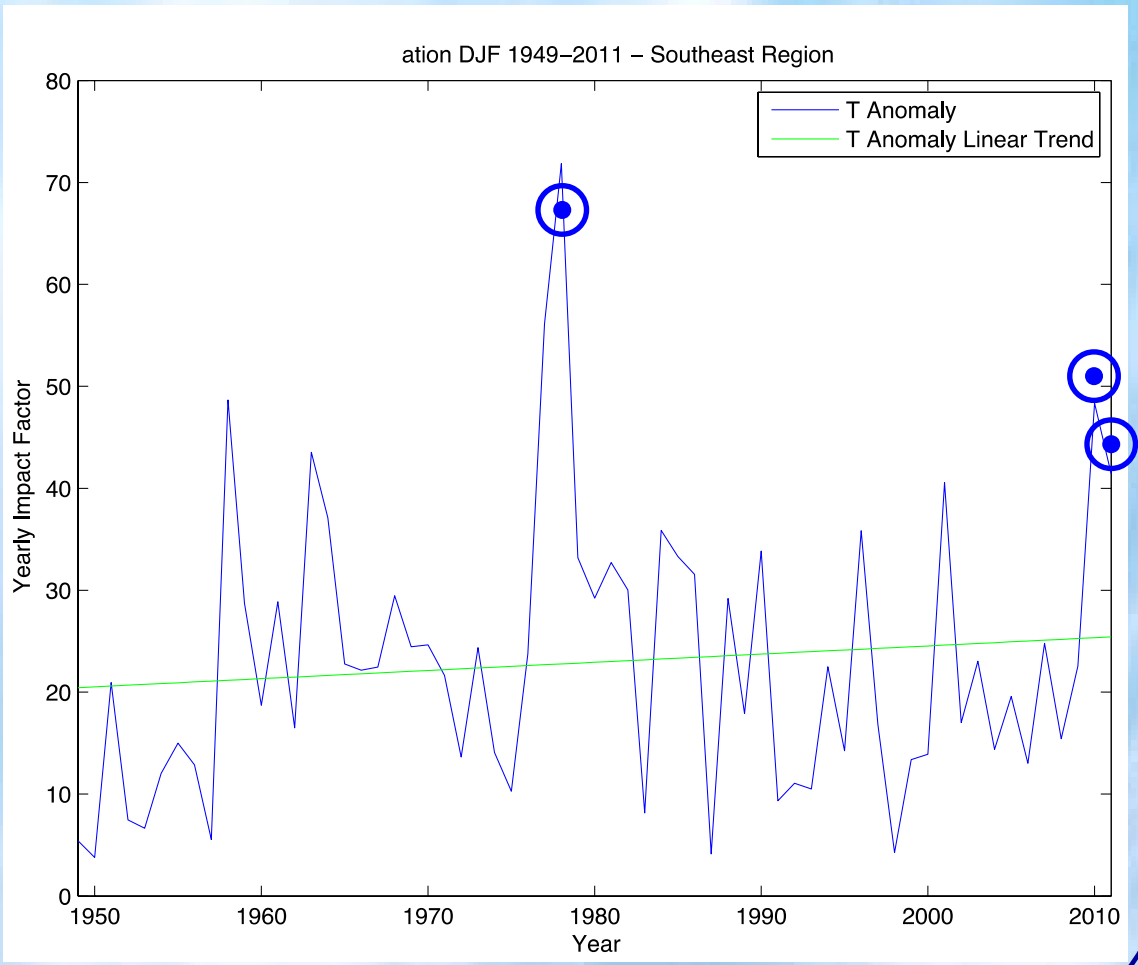
Results: Number of Cold Days in Southeast Region

- ♠ *Assess interannual variability; contrast temperature and wind chill criteria; vary anomaly threshold (-1σ, -1.5σ, -2σ)*
- ♥ *Temperature and wind chill results almost identical*
- ♣ *No statistically significant trends (similar to Walsh et al., 2001)*
- ♦ *Basic conclusions insensitive to anomaly threshold chosen*



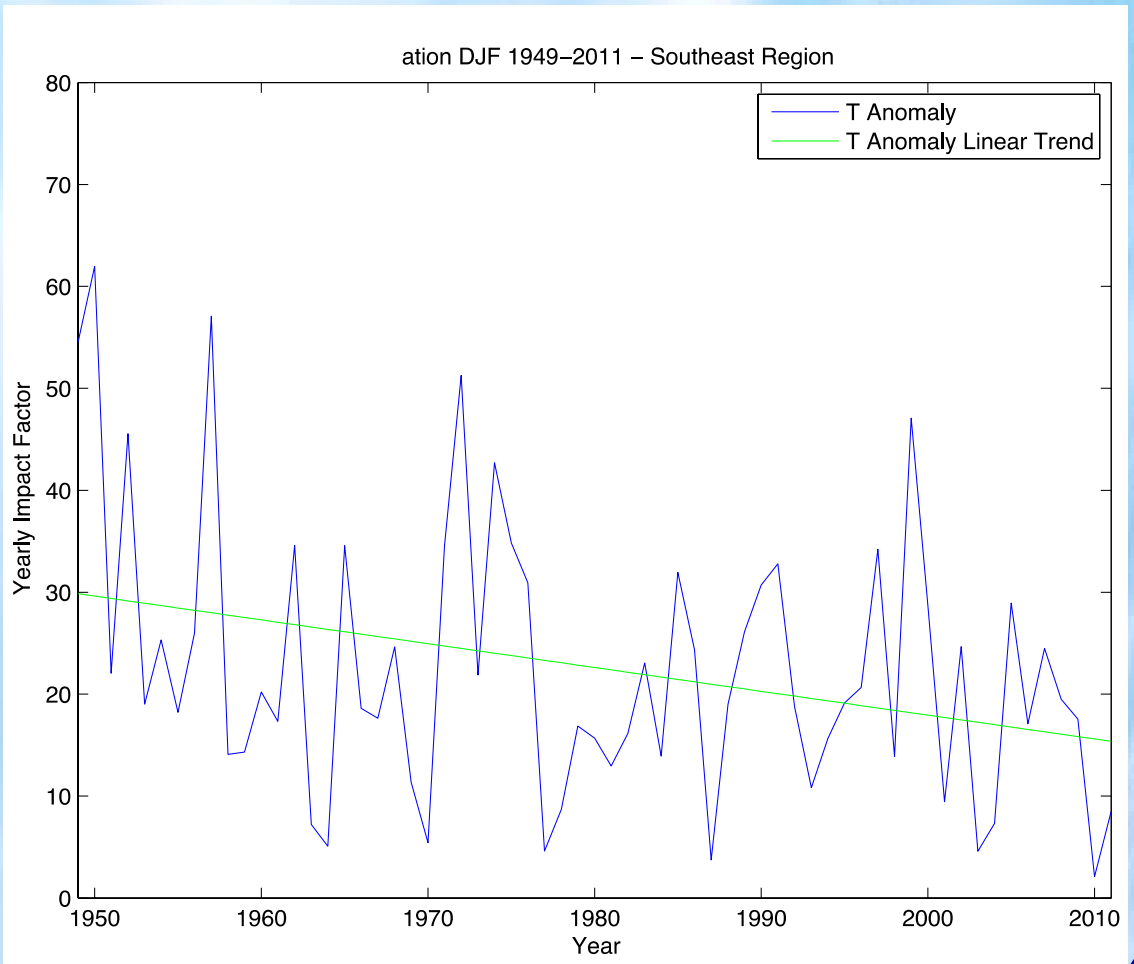
Cold Days in Southeast: # of Days vs. Impact Factor

- ♠ *Relatively little difference observed in interannual behavior*
- ♥ *No significant reduction in frequency or impact factor*
- ♣ *Past 2 winters (09/10 & 10/11) rank in the top 5 among the last 60 years (!)*



Warm Days in Southeast: # of Days vs. Impact Factor

- ♠ *Relatively little difference observed in interannual behavior*
- ♥ *Statistically Significant downward trend*
- ♣ *Very low values during last two winter seasons (09/10 & 10/11)*
- ♦ *Employ Number of Days measure in remaining analyses*



Low Frequency Modulation of Temperature Regimes

Correlation Assessment for the Southeast Region

Low Frequency Mode Correlation for the Southeast

	Number of Cold Days		Number of Warm Days	
	T'	Twc'	T'	Twc'
Seasonal Mean AO Index	-0.48	-0.48	0.45	0.46
Seasonal Mean NAO Index	-0.51	-0.52	0.41	0.43
Seasonal Mean PNA Index	0.27	0.25	-0.60	-0.58
Seasonal Mean PDO Index	0.32	0.31	-0.63	-0.61
Seasonal Mean MEI Index	0.08	0.09	-0.46	-0.43
Seasonal Mean Nino 3.4 Index	0.06	0.07	-0.45	-0.43
Seasonal Mean SOI Index	-0.01	-0.04	0.31	0.27

Significant at the 5% confidence level

Significant at the 10% confidence level

Low Frequency Modulation of Temperature Regimes

Correlation Assessment for the Northeast Region

Low Frequency Mode Correlation for the Northeast

	Number of Cold Days		Number of Warm Days	
	T'	Twc'	T'	Twc'
Seasonal Mean AO Index	-0.30	-0.34	0.56	0.51
Seasonal Mean NAO Index	-0.29	-0.31	0.51	0.48
Seasonal Mean PNA Index	0.10	0.11	-0.24	-0.21
Seasonal Mean PDO Index	0.24	0.25	-0.35	-0.34
Seasonal Mean MEI Index	0.03	0.04	-0.14	-0.13
Seasonal Mean Nino 3.4 Index	0.01	0.04	-0.18	-0.16
Seasonal Mean SOI Index	-0.06	-0.07	0.01	0.01

Significant at the 5% confidence level

Significant at the 10% confidence level

Low Frequency Modulation of Temperature Regimes

Correlation Assessment for the Midwest Region

Low Frequency Mode Correlation for the Midwest

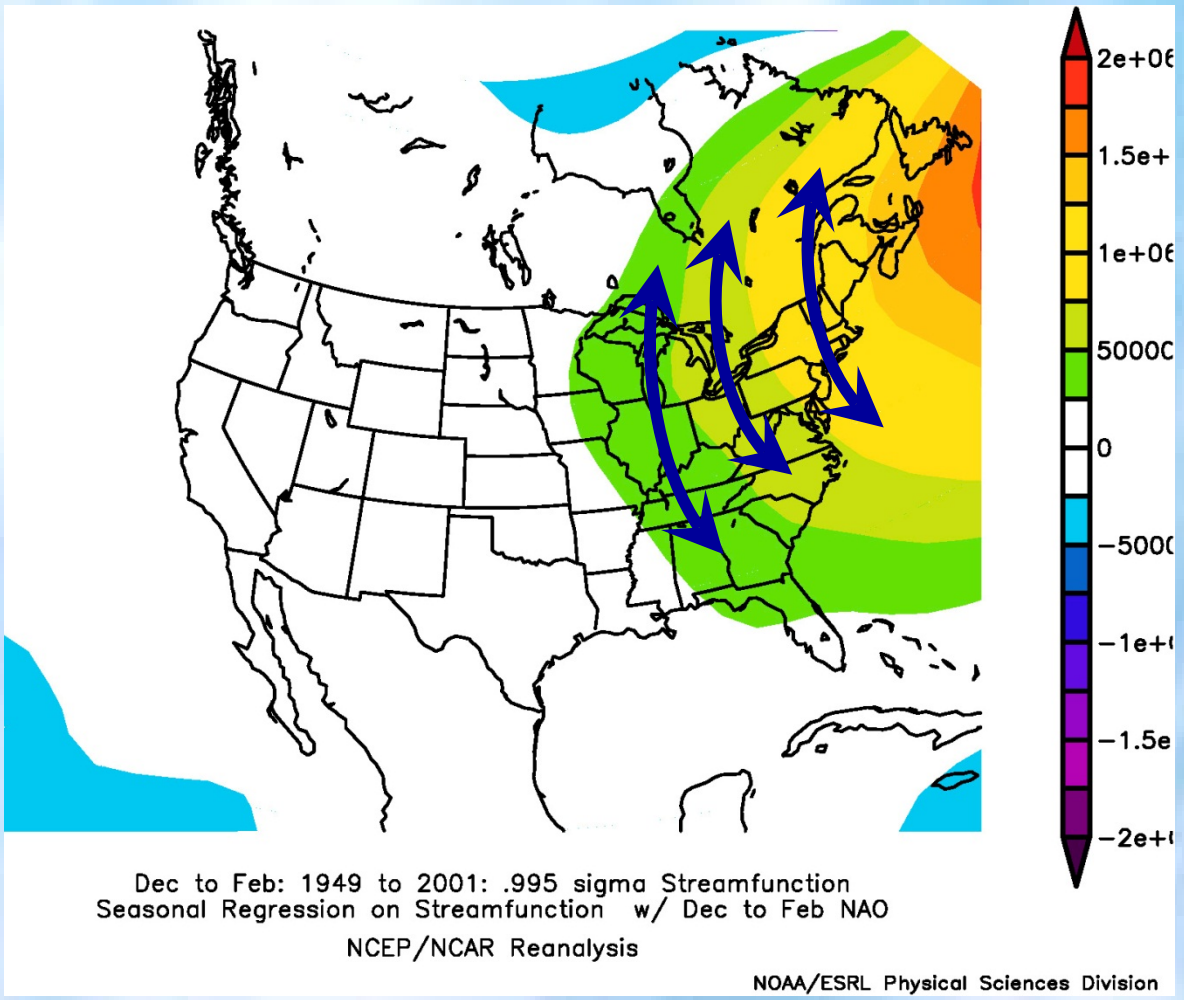
	Number of Cold Days		Number of Warm Days	
	T'	Twc'	T'	Twc'
Seasonal Mean AO Index	-0.24	-0.26	0.40	0.41
Seasonal Mean NAO Index	-0.22	-0.25	0.41	0.43
Seasonal Mean PNA Index	-0.06	-0.02	0.28	0.26
Seasonal Mean PDO Index	0.08	0.13	0.10	0.09
Seasonal Mean MEI Index	-0.13	-0.09	0.24	0.24
Seasonal Mean Nino 3.4 Index	-0.16	-0.12	0.19	0.20
Seasonal Mean SOI Index	0.15	0.12	-0.24	-0.26

Significant at the 5% confidence level

Significant at the 10% confidence level

Regional Influence of Low Frequency Mode: NAO

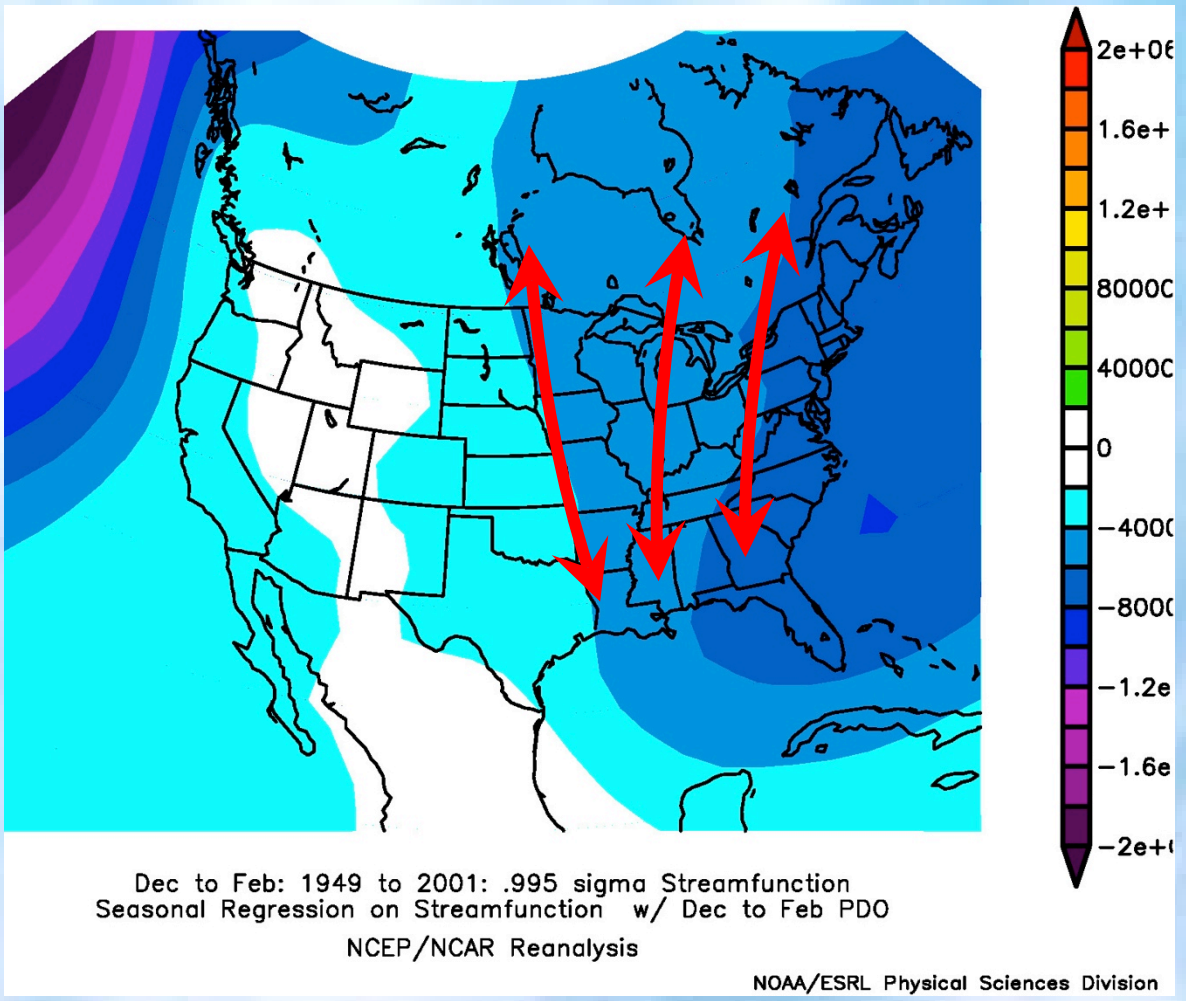
- ♠ *Linear regression of near surface streamfunction w/NAO*
- ♥ *Positive NAO: Anomalous southerly flow over Eastern US*
- ♣ *Negative NAO: Anomalous northerly flow over Eastern US*



Modulation of Kaspi & Schneider (2011) mechanism?

Regional Influence of Low Frequency Mode: PDO

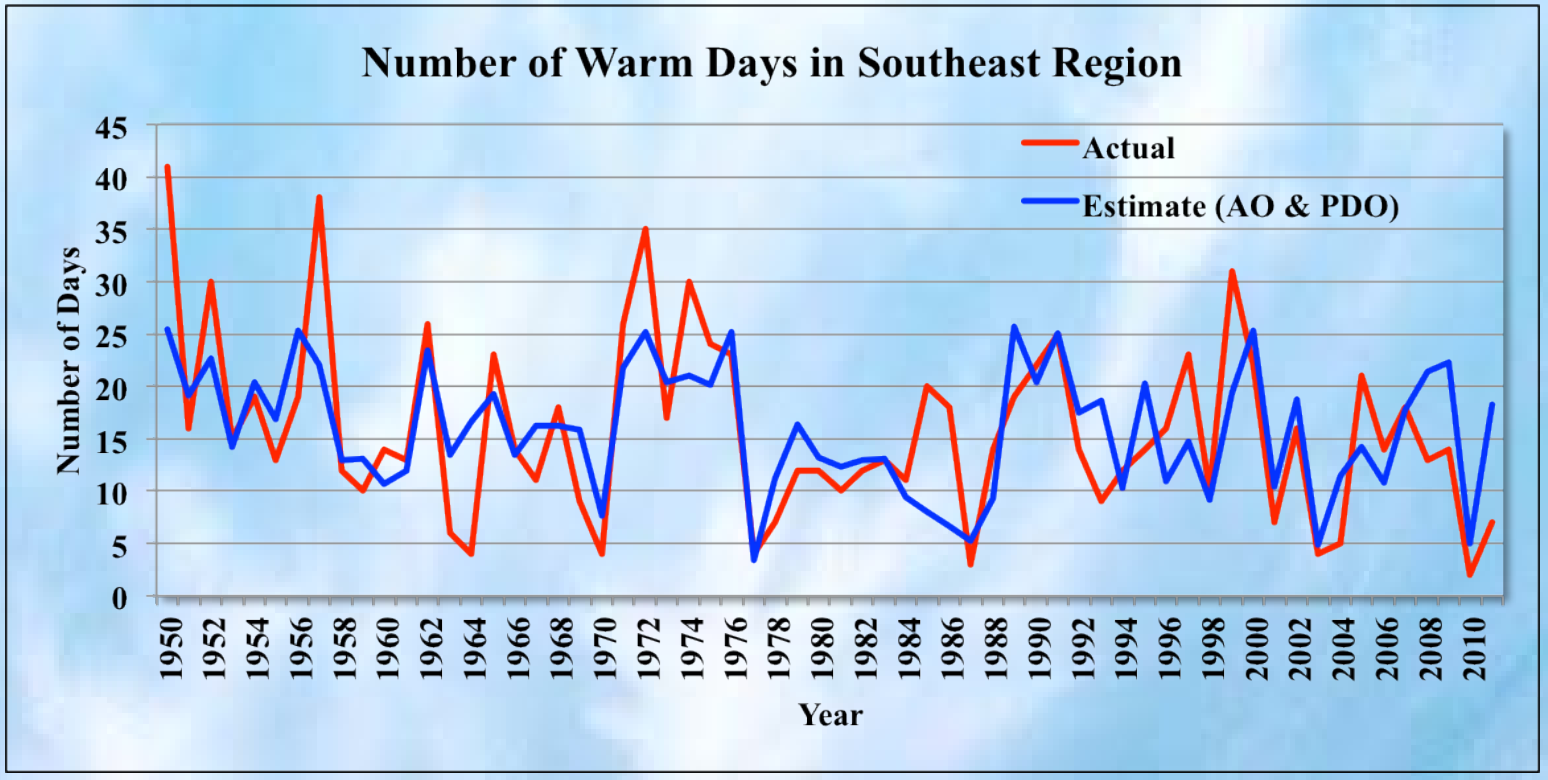
- ♠ *Linear regression of near surface streamfunction w/PDO*
- ♥ ***Positive PDO:*** *Anomalous northerly flow over Eastern US*
- ♣ ***Negative PDO:*** *Anomalous southerly flow over Eastern US*



Role of PDO appears to be more robust than that of PNA

Low Frequency Modulation of Temperature Regimes

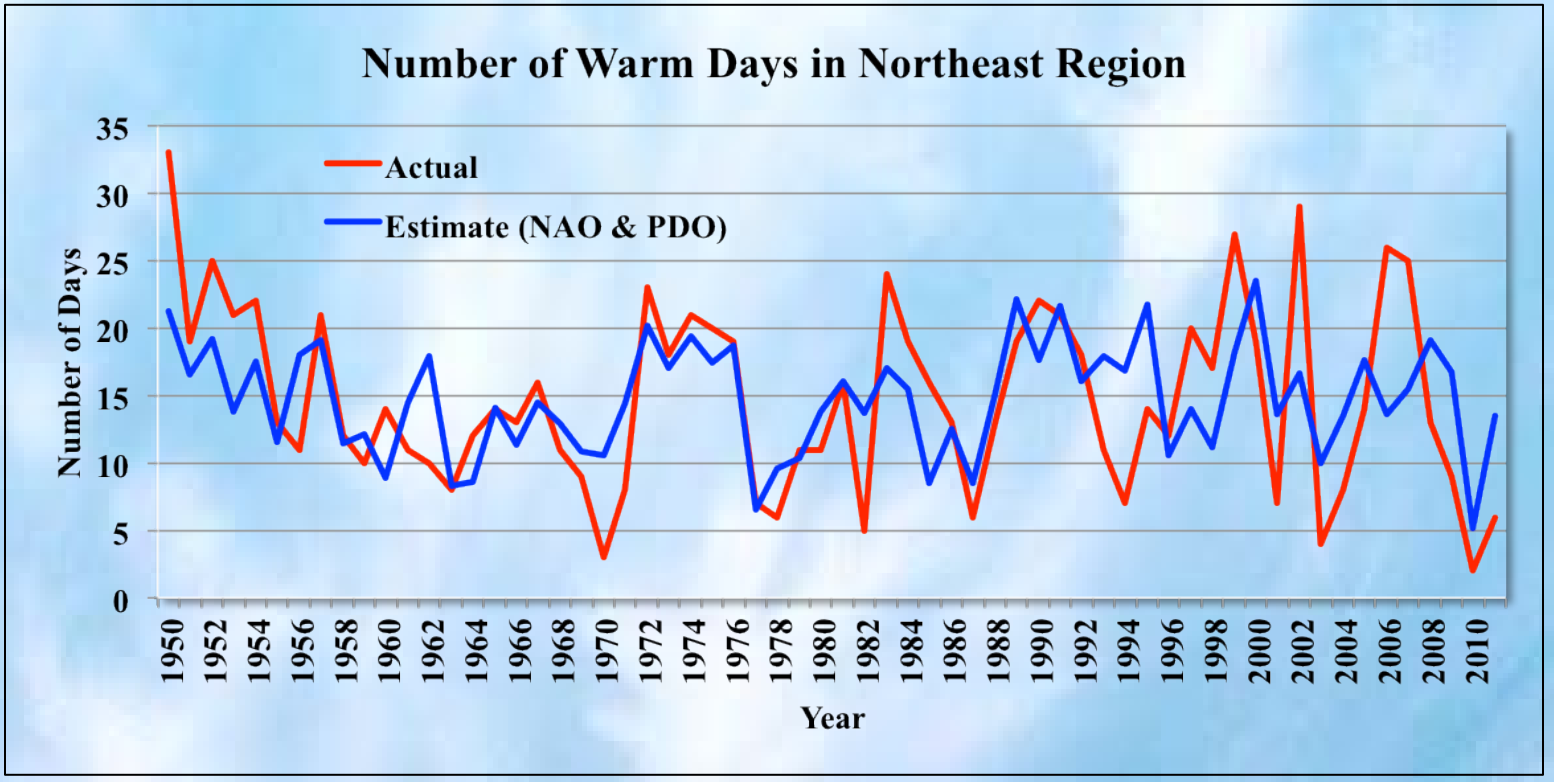
Multiple Linear Regression: Warm Waves in Southeast



- ♠ *Multicollinearity: BKW Variance decomposition*
- ♥ *Residual autocorrelation: No (Durbin-Watson statistic)*
- ♣ *Together AO & PDO account for ~48% of variance*

Low Frequency Modulation of Temperature Regimes

Multiple Linear Regression: Warm Waves in Northeast



- ♠ *Multicollinearity: BKW Variance decomposition*
- ♥ *Residual autocorrelation: Yes (apply Cochrane-Orcutt)*
- ♣ *Together NAO & PDO account for ~31% of variance*

Preliminary Analyses of Model Simulations

♠ *CAM4 1° IPCC-AMIP Ensemble Member #1*
Case Name: f40.1979_amip.track1.1deg.001

♥ *CCSM4 1° 20th Century Ensemble Member #4*
Case Name: b40.20th.track1.1deg.008

♣ *Objectives of diagnostic studies of historical simulations:*

Assess behavior of and long-term variability in ETRs

Assess modulation of ETRs by low frequency modes

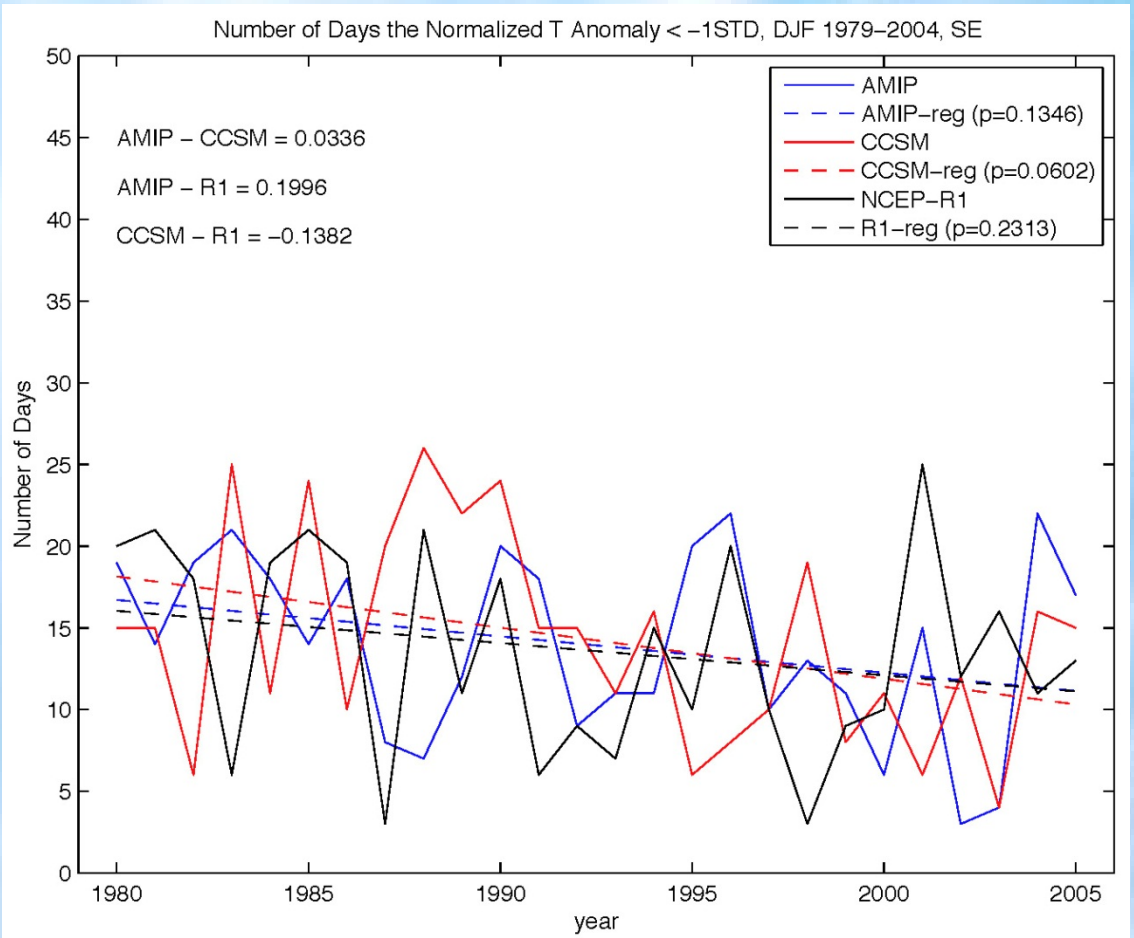
Assess structure and behavior of low frequency modes

Provide feedback on weather-climate representation

♦ *Ultimate objective: Assess likely future changes in ETR behavior and ETR-low frequency mode linkages*

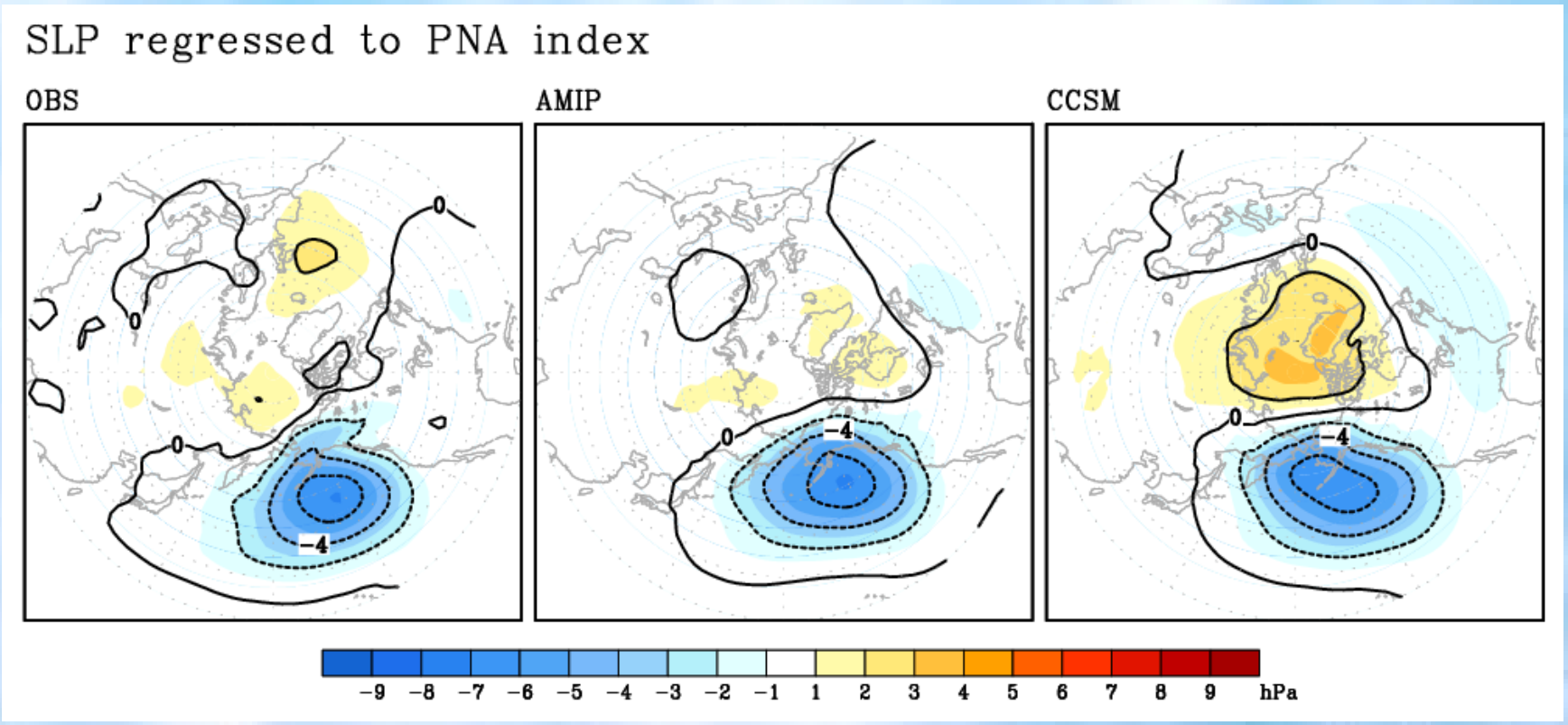
Cold Days in Southeast: NCEP, CAM4 & CCSM4

- ♠ *General nature of interannual behavior appears similar*
- ♥ *No significant trends observed*
- ♣ *Weak correlations among time series (not unexpected)*
- ♦ *Need to examine more simulations & more models (CMIP5)*



Low Frequency Modes: NCEP, CAM4 & CCSM4

Example: Near surface structural manifestation of PNA teleconnection pattern (sea level pressure field)

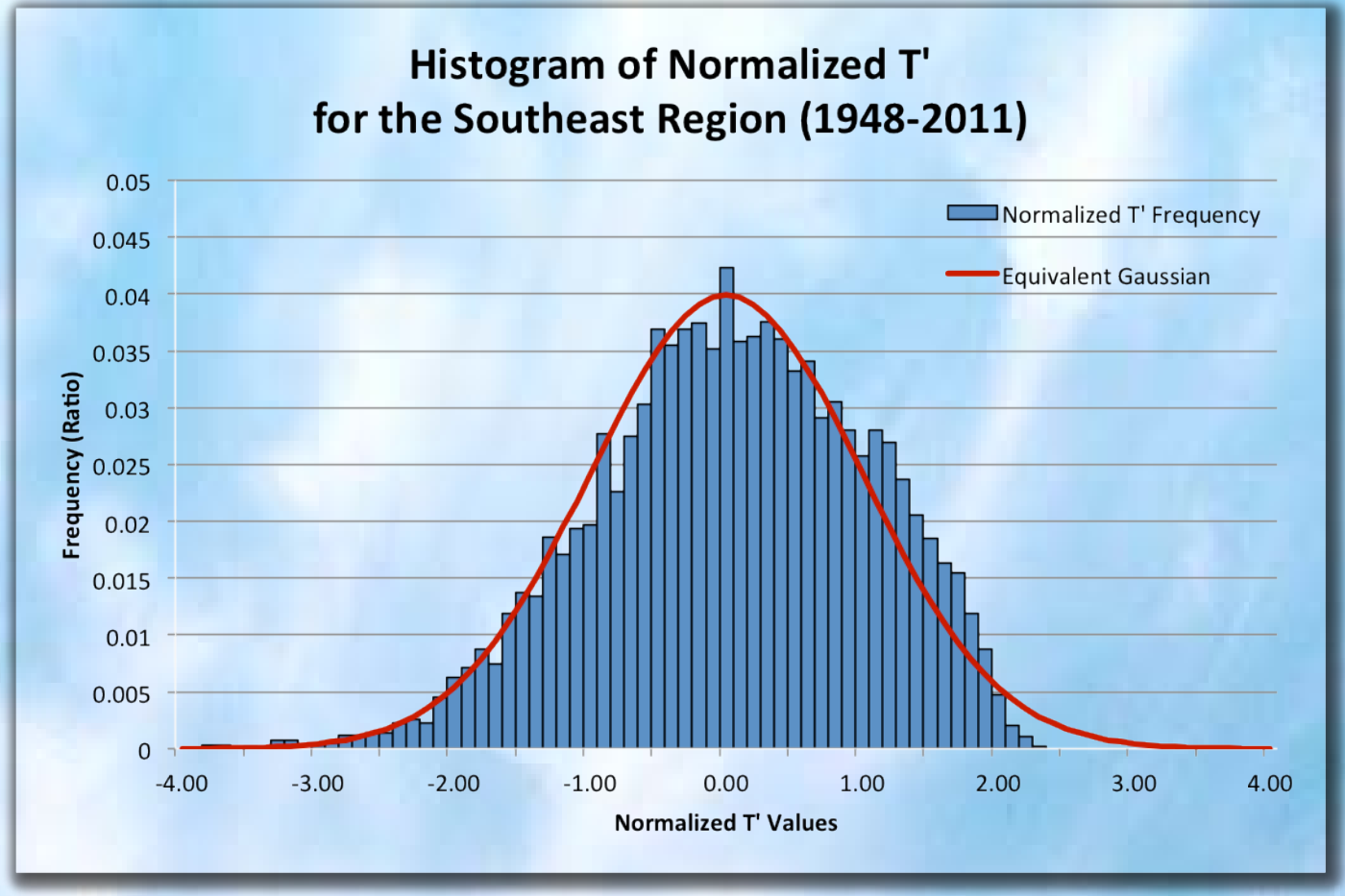


Summary

- ♠ *Cool season warm waves have decreased over Southeast*
- ♥ *No other significant trends are observed (in particular there is no evidence for decreases in cold air outbreaks)*
- ♣ *Winters of 2009/10 & 2010/11 rank in the top 5 most severe in terms of cold air events over the Southeast*
- ♦ *Pronounced interannual modulation of cool season ETRs by leading modes of low frequency variability*
- ♠ *Implication: Accurate representation of regional ETR variability by climate models is critically dependent on the veracity of the simulated low frequency modes*
- ♥ *Near term efforts: Observed life cycles & dynamics; Assessment of ETRs in CMIP5 historical model runs*

Backup Slides

Distribution of Normalized Temperature Anomalies



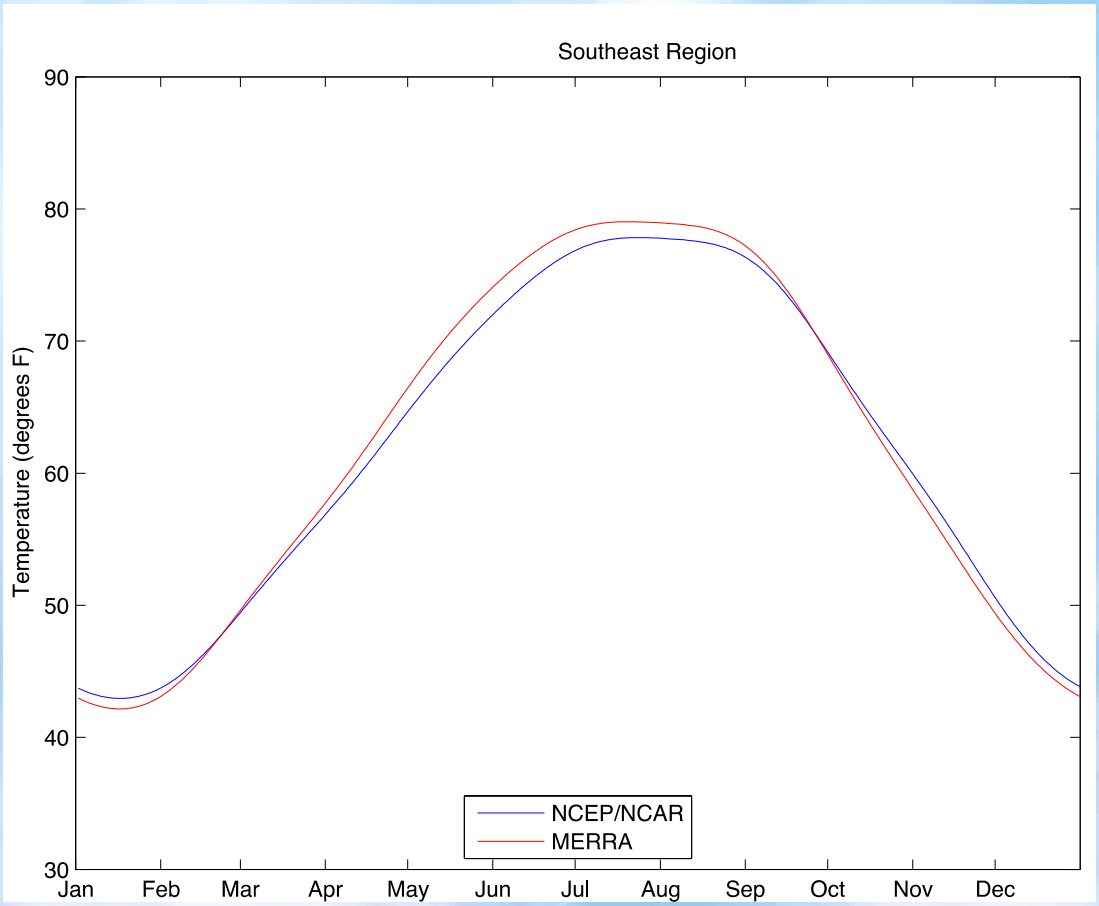
Predominantly symmetric distribution (skewness ≈ -0.28)

Research Approach: Regional Metrics

- ♠ *Sensitivity Analyses:*
- ♥ *1) NCEP/NCAR reanalyses vs. NASA-GMAO MERRA*
- ♣ *2) NCEP/NCAR First 30 years vs. Last 30 years*
- ♦ *Little Sensitivity found in either analysis*

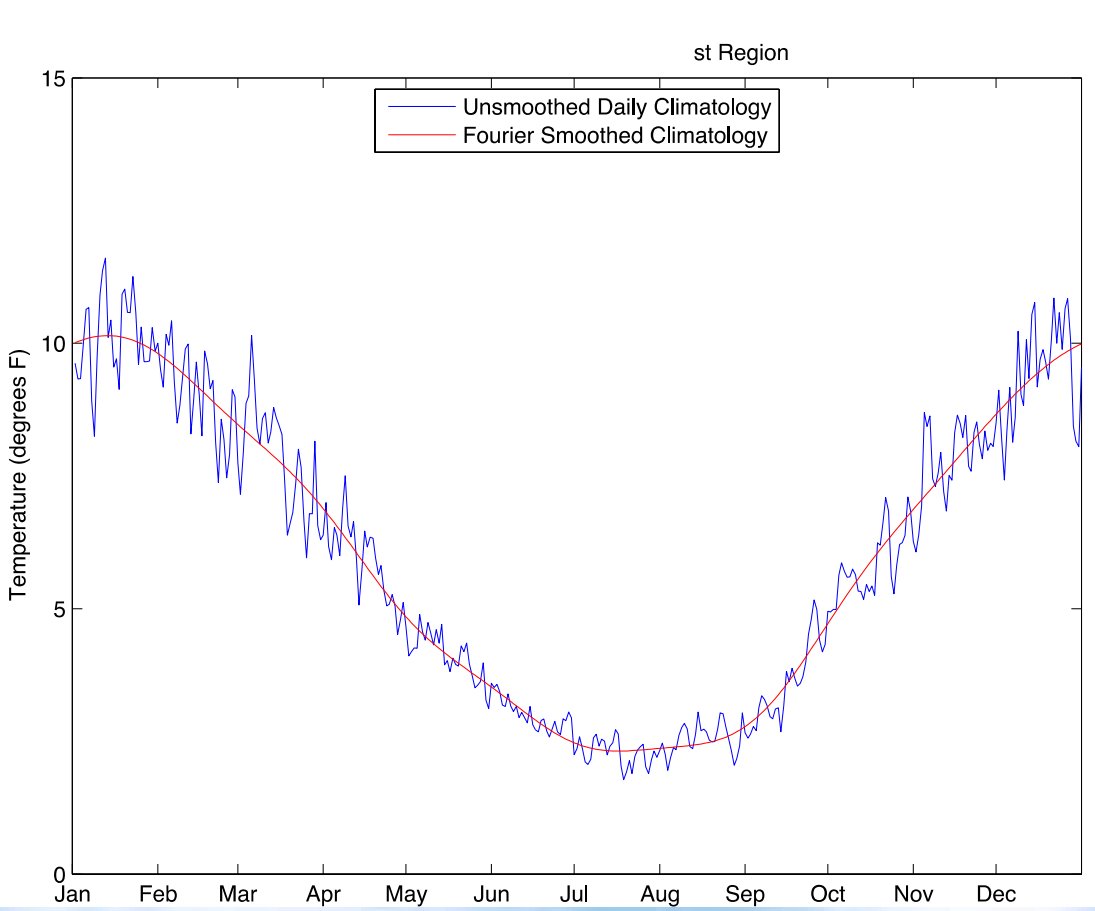
MERRA: Slightly larger amplitude

NCEP: Statistical stationarity



Research Approach: Regional Metrics

- ♠ *The areal average temperature metric is combined among all winters for each calendar day to assess seasonal cycles in the mean and standard deviation.*
- ♥ *Seasonal cycles are smoothed using Fourier analysis (keep 1st 6 harmonics)*
- ♣ *Example: Seasonal cycle for Southeast Region*
  - *mean T (μ)*
  - *standard deviation (σ)*



Wind Chill Definition

$$WCI\ (^{o}F) = 35.74 + 0.6215T - 35.75V^{0.16} + 0.4275TV^{0.16}$$

Where V is the wind speed in m/s & T is air temperature in ^{o}F

Following ***Osczevski and Bluestein 2005***