2011 Long-Term Load Forecast Model Review

ERCOT

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Outline

- **Forecast Overview**
- **Economic Assumptions**
- **Weather Overview and Assumptions**
- **Model Specifications**
- **Forecast Results**
- **Future Enhancements**

Forecast Overview

To create a long-term load forecast requires:

i. Employment or economic data forecast for each county for the duration of the forecasting time-frame

ii. Hourly weather forecast for each weather zone which will be used for each forecasting year

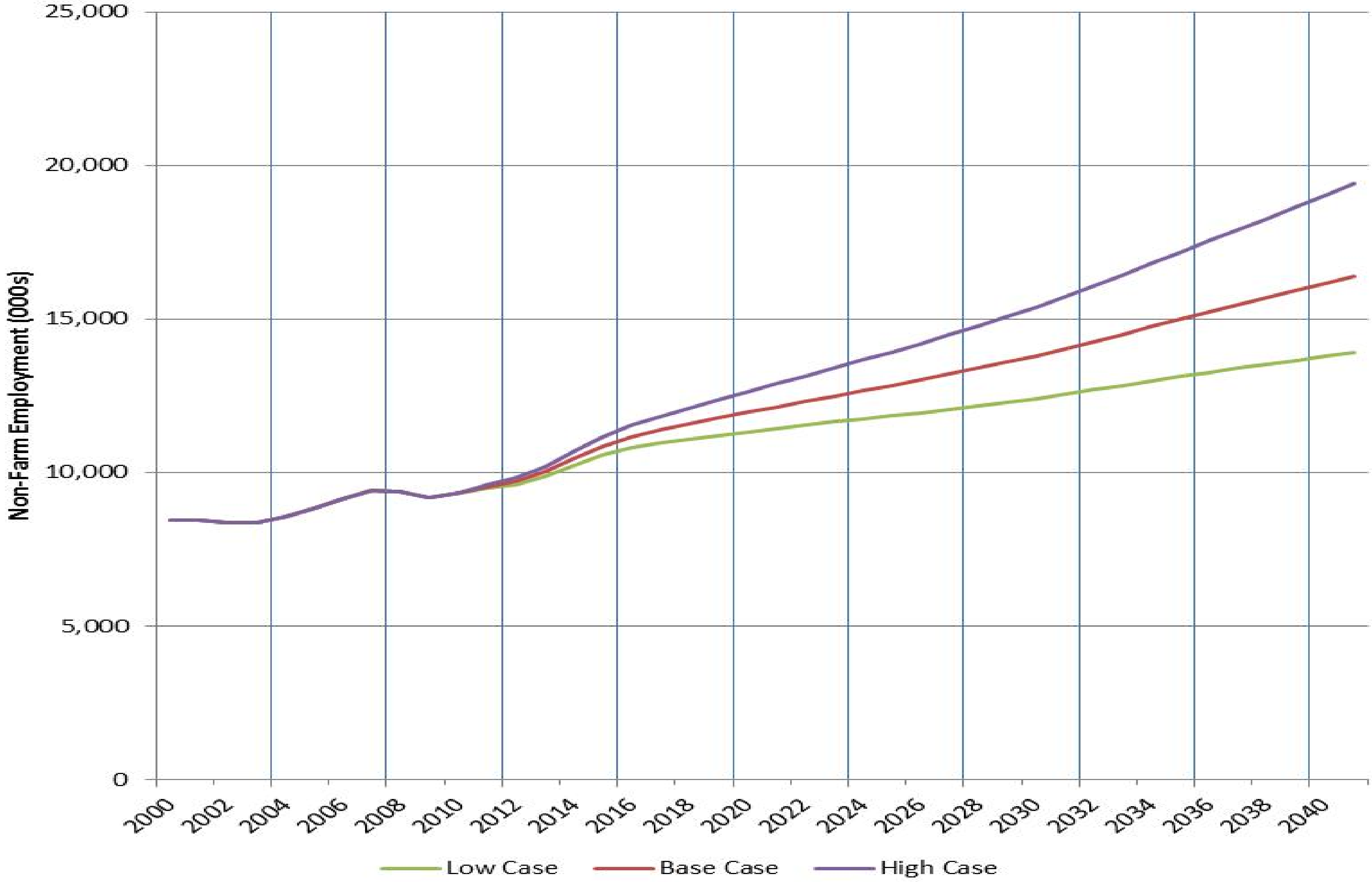
These values are used by forecasting models to create the hourly demand forecasts for ERCOT

Moody's provides ERCOT with three county-level economic forecasts:

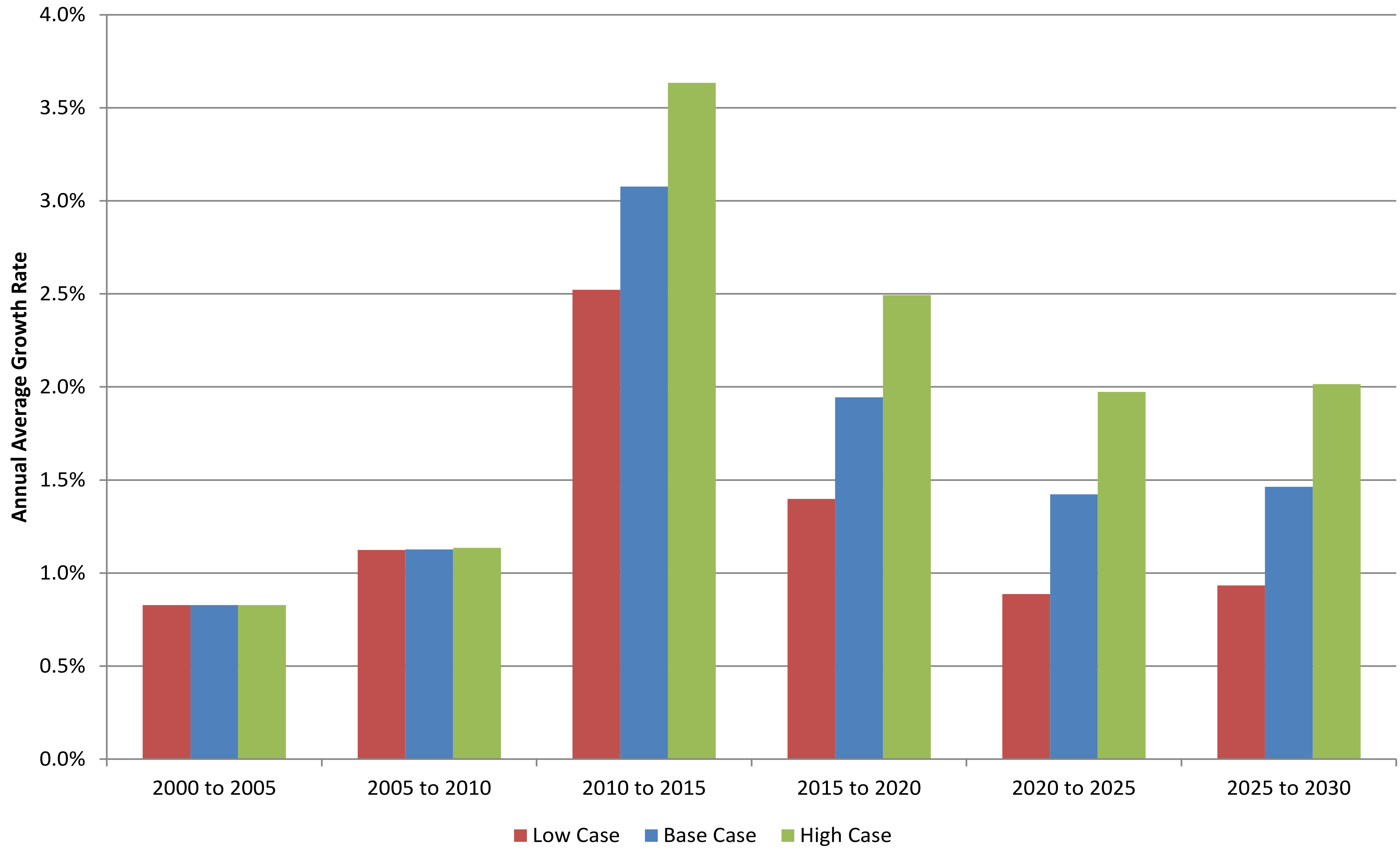
i. **Base**
ii. **High economic growth**
iii. **Low economic growth**

Which forecast should be used?

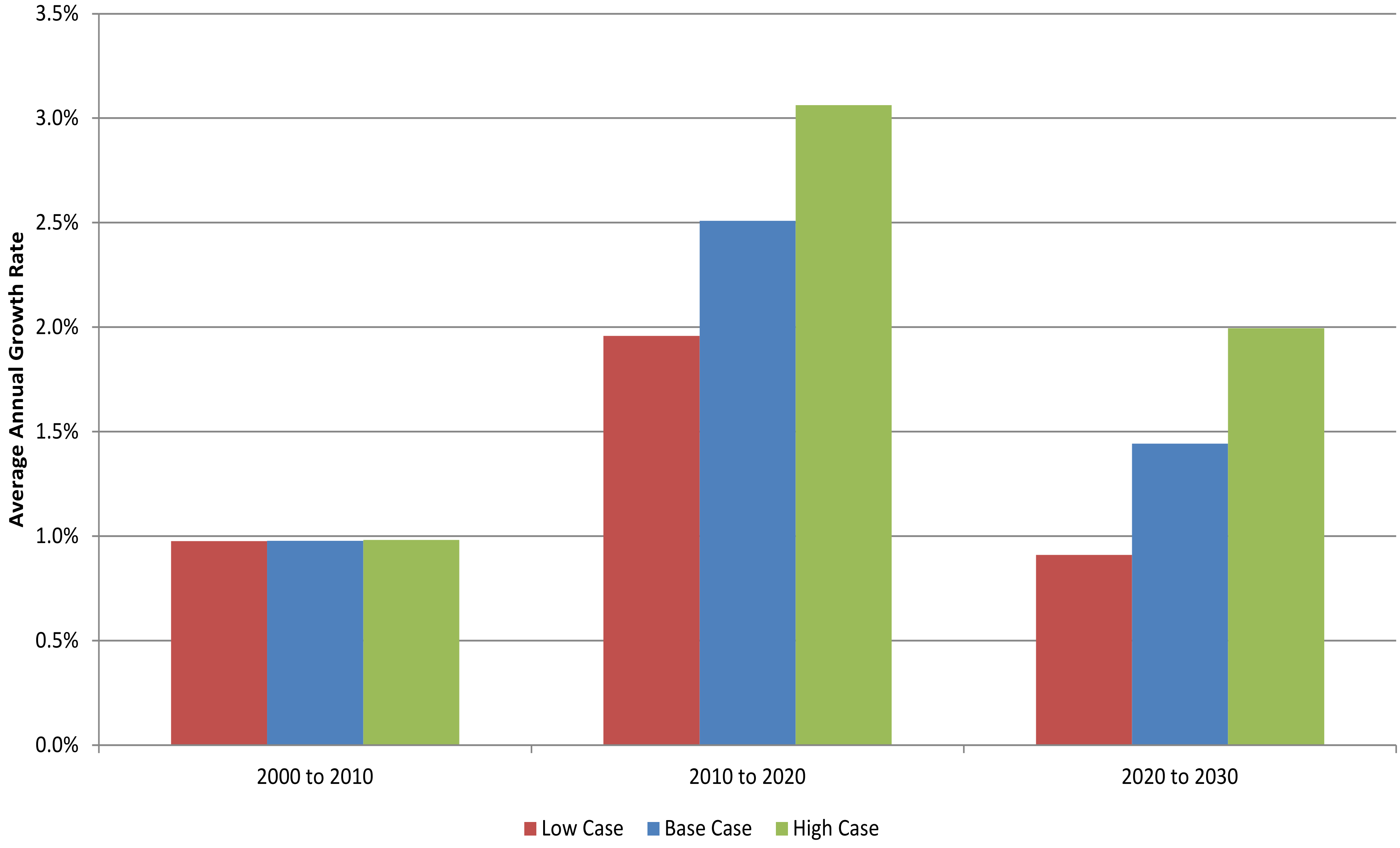
Moody’s Non-Farm Employment Scenarios – 11/8/2011



Moody's Non-Farm Employment Scenarios – 11/8/2011



Moody's Non-Farm Employment Scenarios – 11/8/2011



- **Non-Farm employment values have been tracking close to the base economic forecast for 2010 and 2011**
- **This would appear to support using the base economic forecast for non-farm employment in the 2011 forecast update**
- **So far in 2012, non-farm employment values have been somewhat below Moody's base scenario**

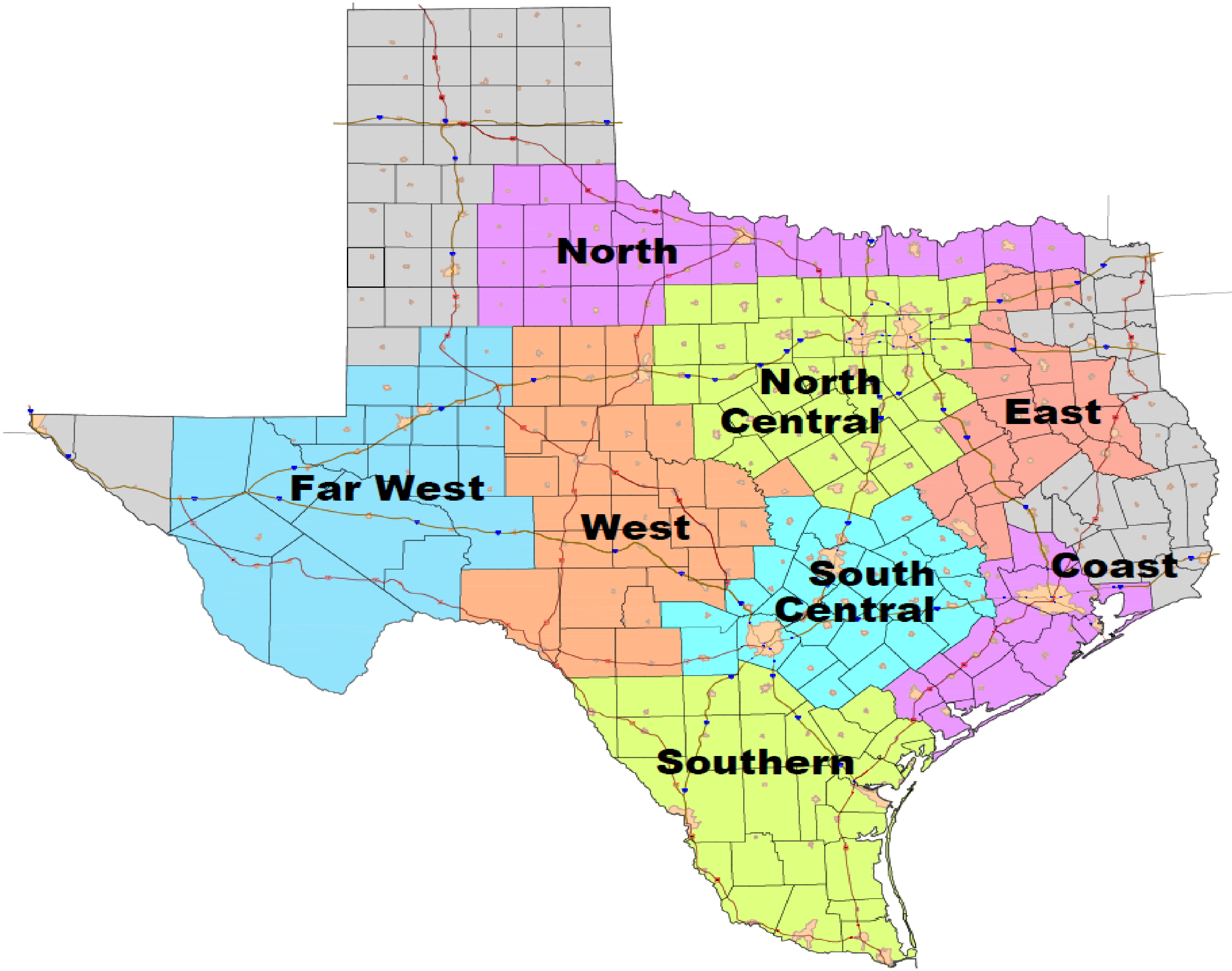
Normal weather definition from NERC LTRA:

"When providing a demand forecast, provide a normalized forecast. This is defined as a forecast which has been adjusted to reflect normal weather, and is expected on a 50% probability basis, i.e., a peak demand forecast level which has a 50% probability of being under or over achieved by the actual peak. This is also known as the 50/50 forecast. This forecast can then be used to test against more extreme conditions."

Extreme weather:

There is increasing interest in extreme weather scenarios such as a 90/10 forecast. The 90/10 forecast has a 10% probability of being exceeded by the actual peak.

Weather Zones



Weather Overview – “Normal” Weather Forecast

- **A “normal” weather forecast is created for each weather zone**

- **The process of creating a “normal” weather forecast has two main steps**

  – Determine the extreme temperature forecast for the month
    - defines the weather conditions for the monthly peak day

  – Determine the monthly average temperature forecast for each month
    - impacts the monthly energy forecast

- **The result is a hourly weather forecast for an entire year**

Weather Overview - Peak Day Weather

- **Maximum and Minimum Forecast temperatures:**
  - The summer peak month is assumed to be August
  - To determine the maximum temperature forecast for August use maximum temperature data for the months of June through September
  - For all of the remaining summer months use maximum temperature data for the individual month only
  - For the winter months use the minimum temperature data for the individual month only
  - Peak days are assigned for each month

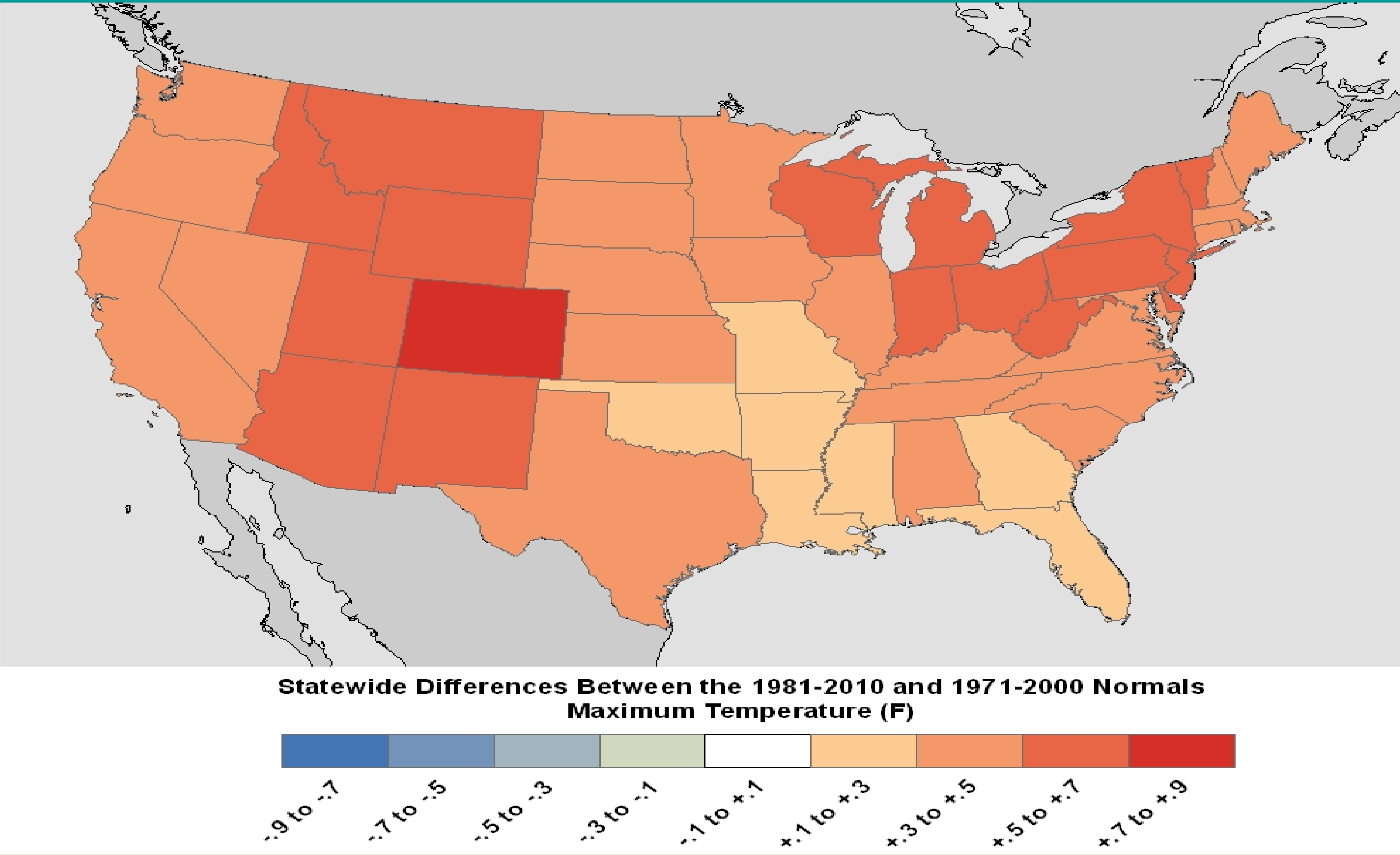
Weather Overview - “Normal” Weather Forecast

- **For each weather zone:**
  - Determine the monthly average temperature forecast for each individual month
  - Merge the forecasted maximum or minimum temperatures into a representative historical month with the resultant monthly average temperature being very close to the historical average temperature
- **The result is a hourly weather forecast for an entire year**
  - Referred to as the “normal” weather forecast

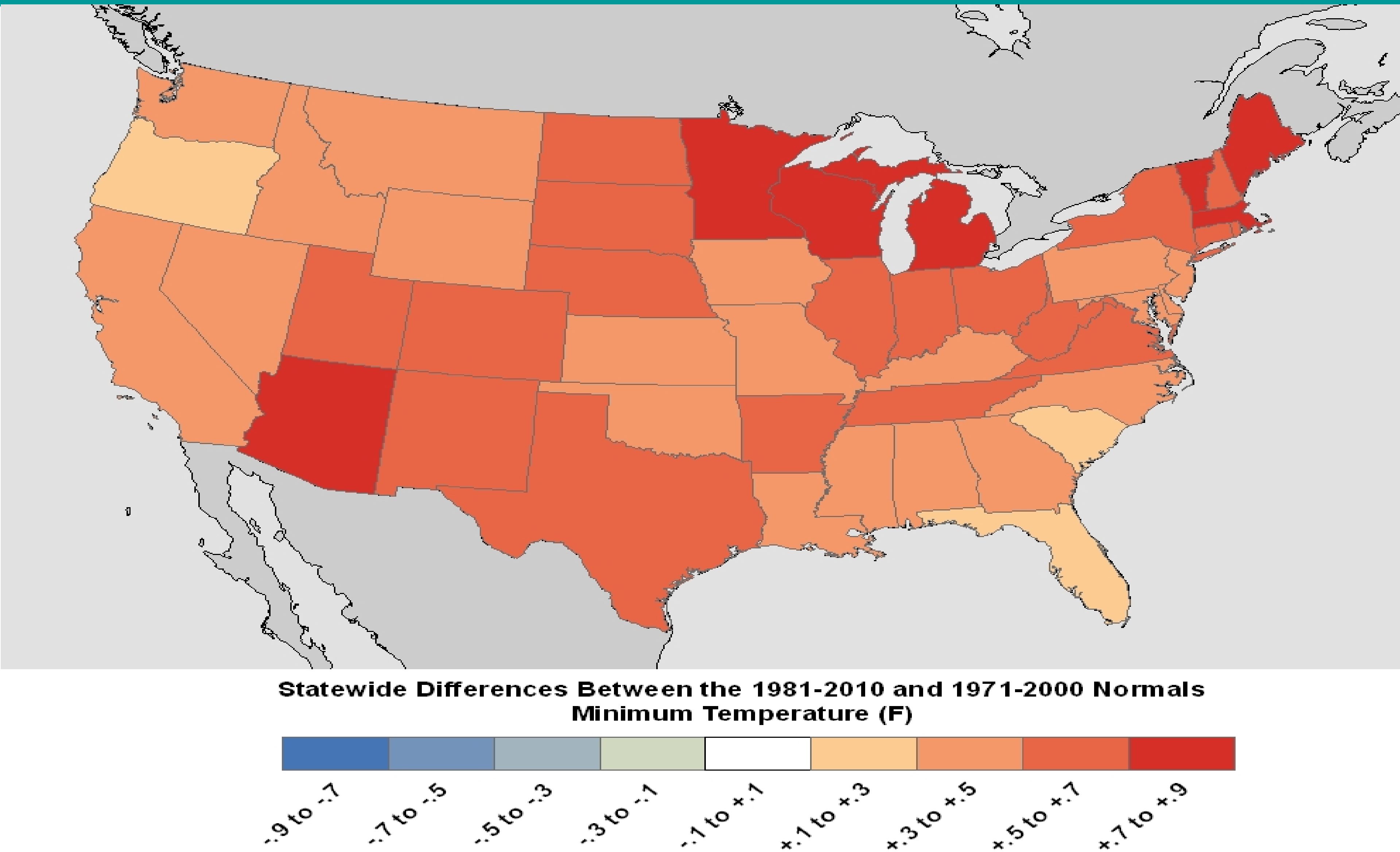
Weather Assumptions

- **Determination of “normal” weather year**
  - What is normal?
  - How many years to include?
    - 30 years
    - 15 years
    - 10 years
  - NOAA updated 30-year normals in 2011 based on data from 1981 to 2010
  - Has resulted in an increase in normal temperatures

NOAA 30-year normal comparison of Maximum Temperature



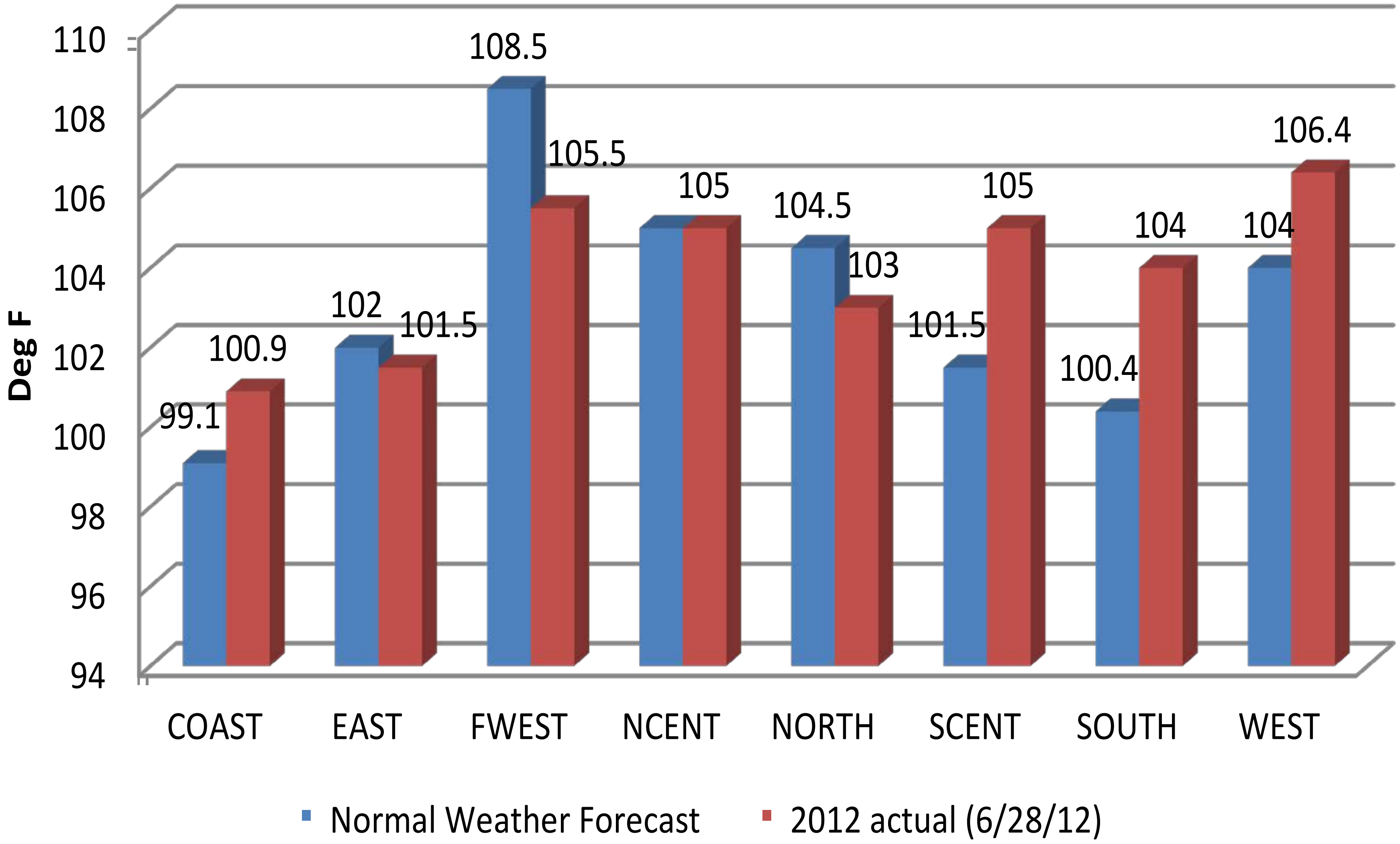
NOAA 30-year normal comparison of Minimum Temperature



- **Because of these weather trends, ERCOT's analysis is based on the most recent 15 years of weather data**

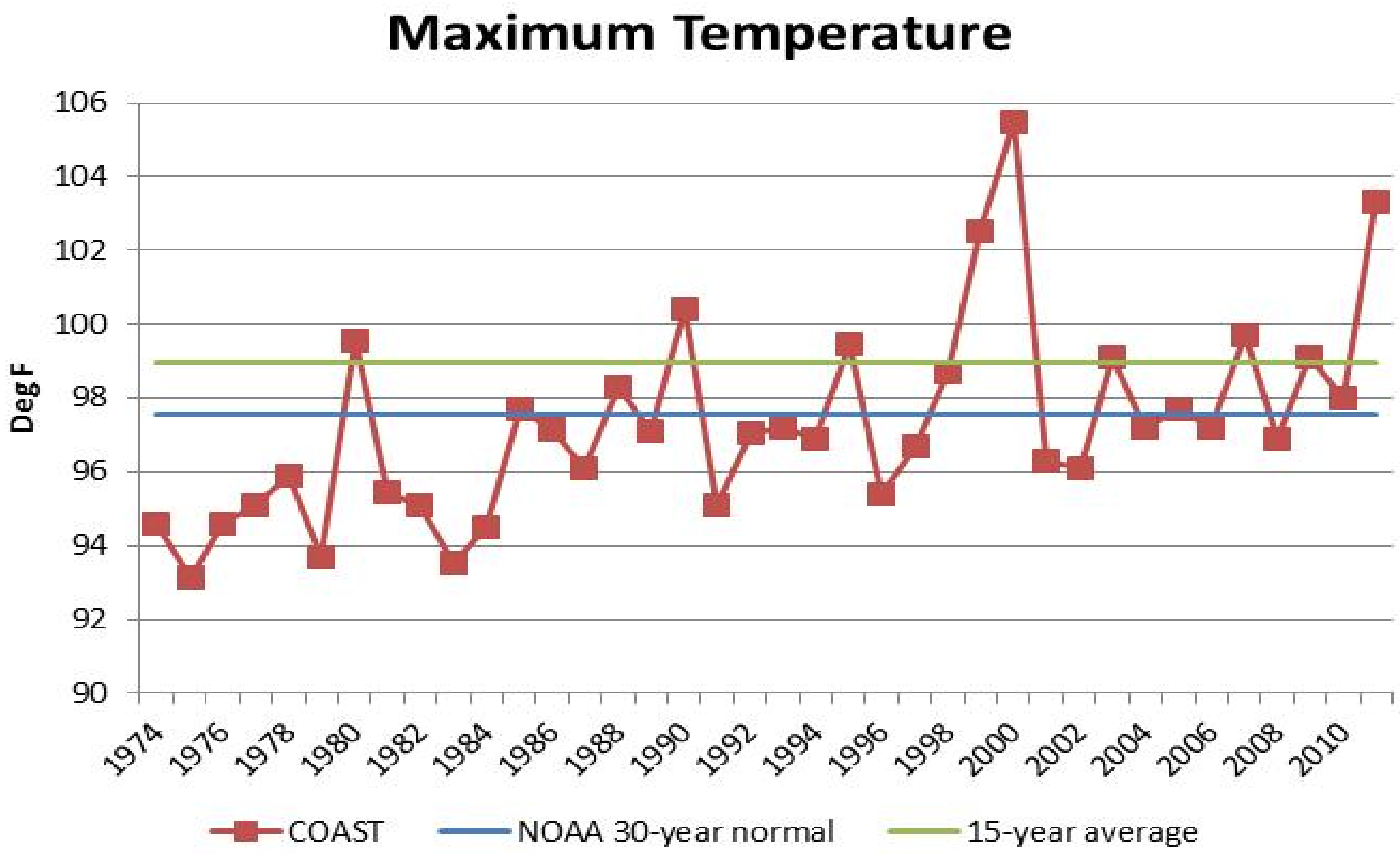
- **Determination of "normal" weather year**
  - There are many ways of deriving a "normal" weather year
    - Based on average temperature
    - Typical meteorological year
    - Rank and Average methodology
    - Based on weather conditions at time of peak
    - Rotating historical weather through a calendar
    - Combinations of the above
  - There is no universally accepted best approach
    - Each of the above has strengths and weaknesses

Summer Annual Maximum Temperatures Summary



Summer Maximum Temperature Forecast Process Details

Summer Annual Maximum Temperatures - COAST



Summer Annual Maximum Temperatures - COAST

- **Determination of summer maximum temperature**
  - Using the most recent 15 years of weather data, calculate the average and the median temperatures

	Max Temp	Rank
1997	96.7	13
1998	98.7	7
1999	102.5	3
2000	105.5	1
2001	96.3	14
2002	96.1	15
2003	99.1	5
2004	97.2	10
2005	97.7	9
2006	97.2	10
2007	99.7	4
2008	96.9	12
2009	99.1	5
2010	98.0	8
2011	103.3	2
Average	98.9	
Median	98.0	

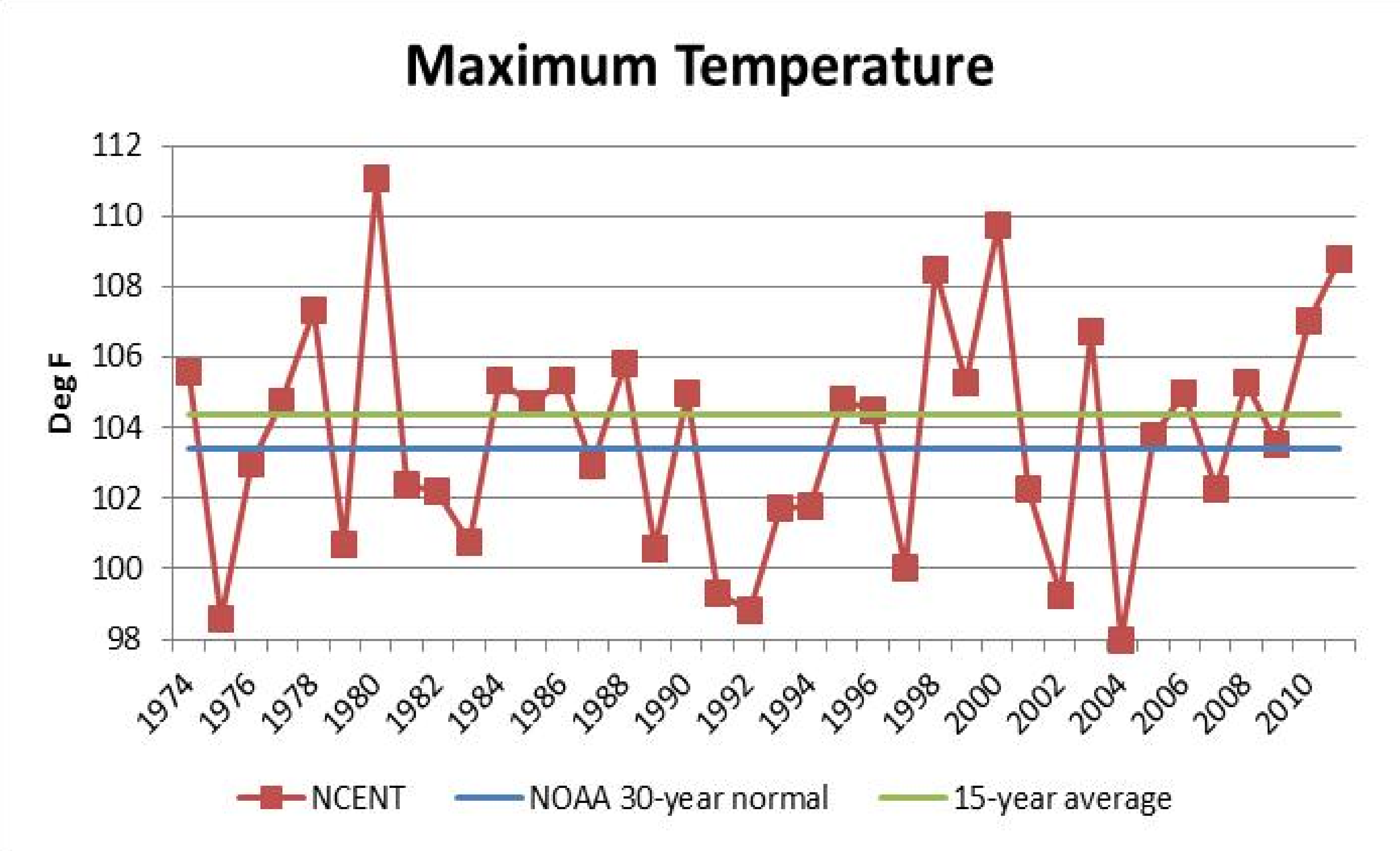
» Select the weather data for the maximum temperature day from the year which has the closest temperature that is greater than or equal to the average

» The maximum temperature day that was selected was from 2003.

» Also include the weather data from the previous day to better represent weather conditions at time of peak

» These two weather days from 2003 are assigned to 8/7 and 8/10

Summer Annual Maximum Temperatures - NCENT



Summer Annual Maximum Temperatures - NCENT

- **Determination of summer maximum temperature**
  - Using the most recent 15 years of weather data, calculate the average and the median temperatures

	Max Temp	Rank
1997	100.0	13
1998	108.5	3
1999	105.3	6
2000	109.8	1
2001	102.3	11
2002	99.3	14
2003	106.8	5
2004	98.0	15
2005	103.8	9
2006	105.0	8
2007	102.3	11
2008	105.3	6
2009	103.5	10
2010	107.0	4
2011	108.8	2
Average	104.4	
Median	105.0	

» Select the weather data for the maximum temperature day from the year which has the closest temperature that is greater than or equal to the average

» The maximum temperature day that was selected was from 2006

» Also include the weather data from the previous day to better represent weather conditions at time of peak

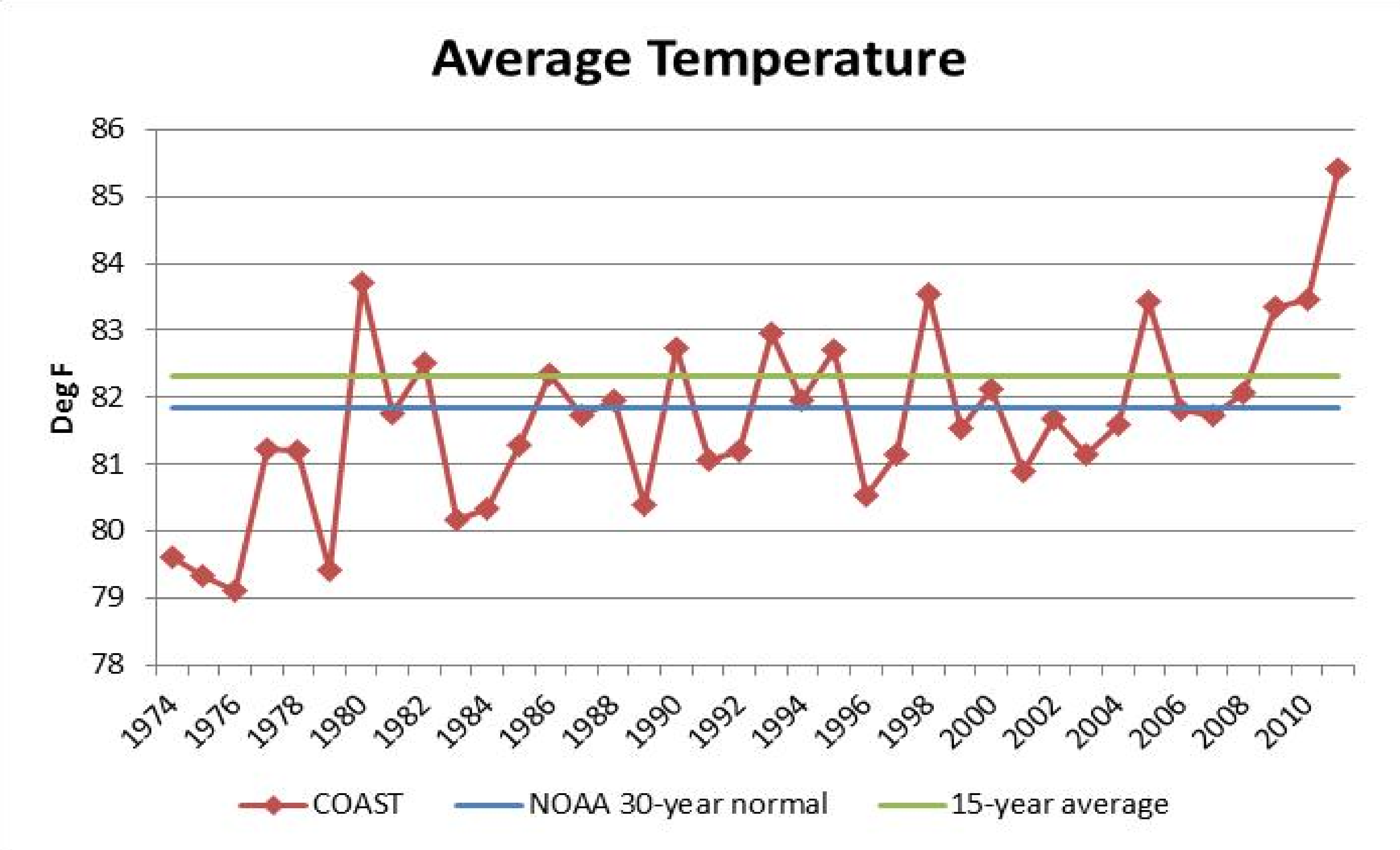
» These two weather days from 2006 are assigned to 8/7 and 8/10

Summary

- **Summer Maximum Temperature Forecast**
  - Determine the annual maximum temperature for the summer months (June – September)
  - Calculate the 15 year average maximum temperature
  - Select the weather data for the maximum temperature day from the year which has the closest temperature that is greater than or equal to the average
  - The day containing the summer maximum temperature and the preceding day are assigned to August
  - These two days represent the weather conditions at the time of the monthly peak
  - Assign the maximum temperatures to 8/7 and 8/10. This ensures that peak weather conditions occur on a weekday

Summer Months
Temperature Forecast
Process Details

Summer Annual Average Temperatures - COAST



August Annual Average Temperatures - COAST

- **Determination of August temperature forecast**
  - Using the most recent 15 years of weather data, calculate the average and the median temperatures

year	month	Average Temp	Rank
1997	8	83.0	12
1998	8	83.4	9
1999	8	85.0	4
2000	8	84.0	7
2001	8	82.9	13
2002	8	83.2	11
2003	8	83.2	10
2004	8	82.4	15
2005	8	84.1	6
2006	8	84.2	5
2007	8	84.0	8
2008	8	82.9	14
2009	8	85.2	3
2010	8	86.4	2
2011	8	88.4	1
	Average	84.2	
	Median	84.0	

» Only uses data for the month of August

» Notice that the each of the last three years have been the progressively warmer

August Annual Average Temperatures - COAST

- **Determination of August temperature forecast**
  – Merge the maximum temperature into a historical month while maintaining the target average temperature. Also include the previous day to account for peak conditions.

year	month	Average Temp	Rank	Max Temp
1997	8	83.0	12	96.0
1998	8	83.4	9	98.7
1999	8	85.0	4	102.5
2000	8	84.0	7	102.3
2001	8	82.9	13	96.3
2002	8	83.2	11	96.1
2003	8	83.2	10	99.1
2004	8	82.4	15	97.2
2005	8	84.1	6	97.1
2006	8	84.2	5	96.4
2007	8	84.0	8	99.7
2008	8	82.9	14	96.1
2009	8	85.2	3	96.9
2010	8	86.4	2	98.0
2011	8	88.4	1	103.3
	Average	84.2		
	Median	84.0		

» Need to change the maximum temperature in the selected historical month to be 99.1 degrees (from slide 21)

» Need to include the maximum temperature on a predetermined peak day (8/7) and three days later (8/10) to ensure that forecasted peak conditions will occur on a weekday

- **Determination of August temperature forecast**
  – Merge the maximum temperature into a historical month while maintaining the target average temperature. Also include the previous day to account for peak conditions.

year	month	Average Temp	Rank	Max Temp
1997	**8**	83.0	12	96.0
1998	**8**	83.4	9	98.7
1999	**8**	85.0	4	102.5
2000	**8**	84.0	7	102.3
2001	**8**	82.9	13	96.3
2002	**8**	83.2	11	96.1
2003	**8**	83.2	10	99.1
2004	**8**	82.4	15	97.2
2005	**8**	84.1	6	97.1
2006	**8**	84.2	5	96.4
2007	**8**	84.0	8	99.7
2008	**8**	82.9	14	96.1
2009	**8**	85.2	3	96.9
2010	**8**	86.4	2	98.0
2011	**8**	88.4	1	103.3
	Average	84.2		
	Median	84.0		

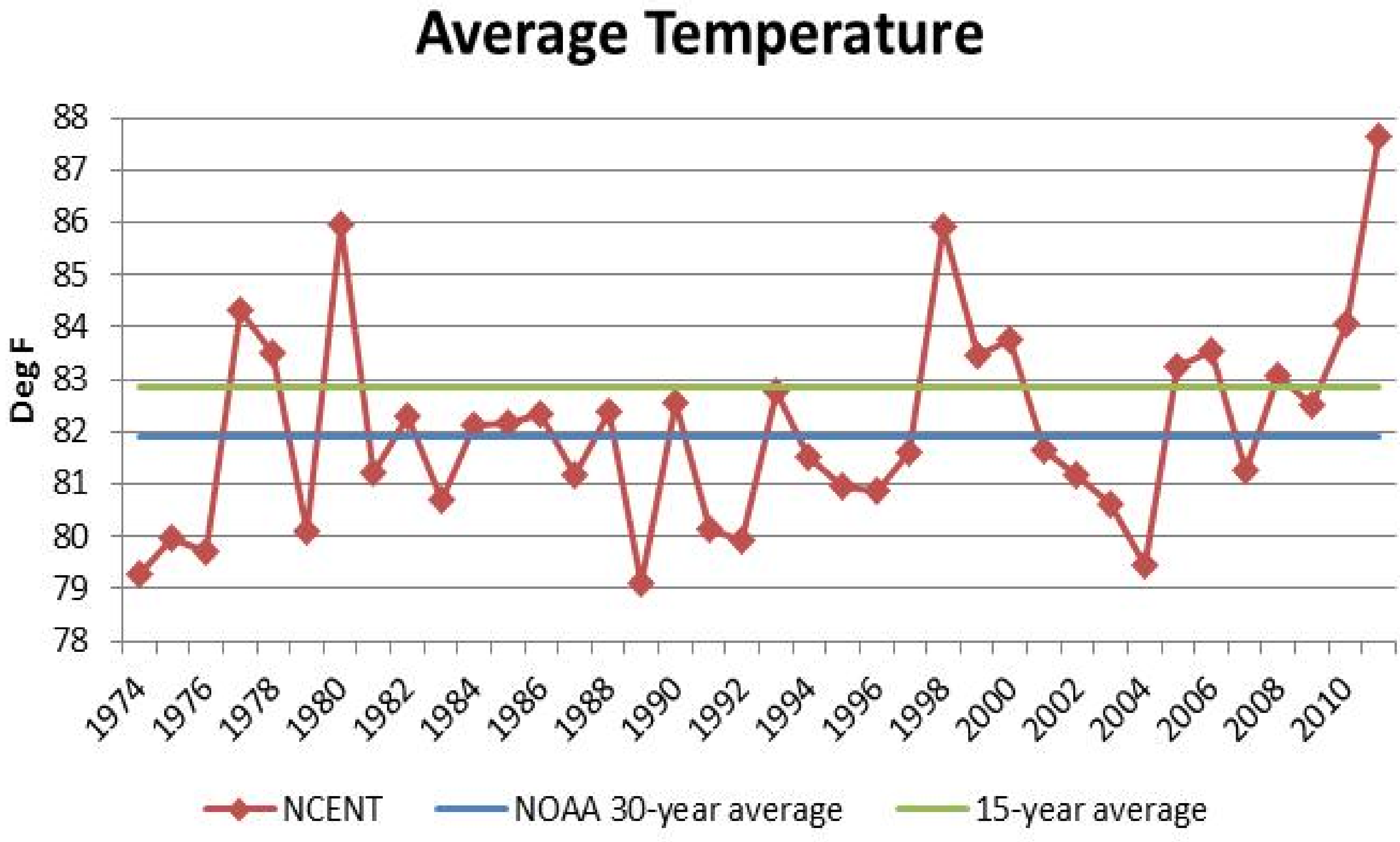
» After adjusting the selected historical month's maximum temperature, need to ensure that the monthly average temperature is very close to 84.2 degrees

» This is an iterative process involving multiple historical years in order to determine the best fit

Example

- **COAST**
  - For example, the desired maximum temperature for the COAST weather zone is 99.1 degrees (slide 21)
  - The historical August that was selected was 2007 which had a maximum temperature of 99.7 degrees. The maximum temperature for this month was reduced to 99.1 degrees by replacing the maximum temperature day with the desired forecasted maximum temperature day (8/7). The day preceding the maximum temperature day was also replaced.
  - The new maximum temperature day (99.1 degrees) and its preceding day are copied to 8/10 to ensure that maximum temperature conditions occur on a weekday for each forecasted year.

Summer Annual Average Temperatures - NCENT



August Annual Average Temperatures - NCENT

- **Determination of August temperature forecast**
  - Using the most recent 15 years of weather data, calculate the average and the median temperatures

year	month	Average Temp	Rank
1997	8	83.0	14
1998	8	86.2	6
1999	8	89.3	2
2000	8	89.1	3
2001	8	84.6	10
2002	8	84.5	11
2003	8	84.9	9
2004	8	80.4	15
2005	8	84.1	13
2006	8	88.2	5
2007	8	85.5	7
2008	8	84.2	12
2009	8	85.0	8
2010	8	88.7	4
2011	8	92.6	1
	Average	86.0	
	Median	85.5	

» Only uses data for the month of August

» Notice that 2011 was more than 3 degrees warmer than the second warmest August

August Annual Average Temperatures - NCENT

- **Determination of August temperature forecast**
  - Merge the maximum temperature into a historical month while maintaining the target average temperature. Also include the previous day to account for peak conditions.

year	month	Average Temp	Rank	Max Temp
1997	**8**	83.0	14	98.5
1998	**8**	86.2	6	106.0
1999	**8**	89.3	2	105.3
2000	**8**	89.1	3	106.0
2001	**8**	84.6	10	102.3
2002	**8**	84.5	11	98.8
2003	**8**	84.9	9	106.8
2004	**8**	80.4	15	98.0
2005	**8**	84.1	13	100.8
2006	**8**	88.2	5	103.8
2007	**8**	85.5	7	102.3
2008	**8**	84.2	12	105.3
2009	**8**	85.0	8	100.0
2010	**8**	88.7	4	107.0
2011	**8**	92.6	1	108.8
	Average	86.0		
	Median	85.5		

» Need to change the maximum temperature in the selected historical month to be 105 degrees (from slide 23)

» Need to include the maximum temperature on a predetermined peak day (8/7) and three days later (8/10) to ensure that forecasted peak conditions will occur on a weekday

- **Determination of August temperature forecast**
  - Merge the maximum temperature into a historical month while maintaining the target average temperature. Also include the previous day to account for peak conditions.

year	month	Average Temp	Rank	Max Temp
1997	**8**	83.0	14	98.5
1998	**8**	86.2	6	106.0
1999	**8**	89.3	2	105.3
2000	**8**	89.1	3	106.0
2001	**8**	84.6	10	102.3
2002	**8**	84.5	11	98.8
2003	**8**	84.9	9	106.8
2004	**8**	80.4	15	98.0
2005	**8**	84.1	13	100.8
2006	**8**	88.2	5	103.8
2007	**8**	85.5	7	102.3
2008	**8**	84.2	12	105.3
2009	**8**	85.0	8	100.0
2010	**8**	88.7	4	107.0
2011	**8**	92.6	1	108.8
	Average	86.0		
	Median	85.5		

» After adjusting the selected historical month’s maximum temperature, need to ensure that the monthly average temperature is very close to 86 degrees

» This is an iterative process involving multiple historical years in order to determine the best fit

Creating a “Normal” Weather Forecast for Summer Months

- **Monthly Temperature Forecast for Summer Months**
  - Determine the average temperature for the month for each year
  - Calculate the 15-year average temperature for the month
  - Select a historical year that is close to the 15-year average temperature for the month
  - Replace the maximum temperature day and the preceding day from the historical year with the forecasted peak day and its preceding day

Creating a “Normal” Weather Forecast for Peak Days

- **Monthly Temperature Forecast Summer Months**
  - Also add the forecasted peak day and its preceding day to the day which is three days later to ensure that the peak conditions occur on a weekday
  - The forecasted monthly weather profile will need to be very close to the 15-year average temperature after including the peak weather conditions (iterative process)

Winter Months
Temperature Forecast
Process Details

- **Monthly Temperature Forecast for Winter Months**
  - Determine the average temperature for the month for each year
  - Calculate the 15-year average temperature for the month
  - Select a historical year that is close to the 15-year average temperature for the month
  - Replace the minimum temperature day and the preceding day from the historical year with the forecasted peak day and its preceding day

- **Monthly Temperature Forecast Winter Months**
  - Also add the forecasted peak day and its preceding day to the day which is three days later to ensure that the peak conditions occur on a weekday
  - The forecasted monthly weather profile will need to be very close to the 15-year average temperature after including the peak weather conditions (iterative process)

Maximum Temperature Forecast
Other Summer Months
Process Details

Maximum Temperature Forecast – Other Summer Months

- **For April through July and September through November**
  - Process is very similar to the one used to determine the summer maximum temperature
  - The only difference is that the maximum temperatures are based only on historical temperatures for the individual month

Maximum Temperature Forecast – Other Summer Months

- **Other Summer Months Maximum Temperature Forecast**
  - Determine the annual maximum temperature for the individual month
  - Calculate the 15-year average maximum temperature
  - Select the weather data for the maximum temperature day from the year which has the closest temperature that is greater than or equal to the average
  - The day containing the maximum temperature and the preceding day will be used to represent the weather conditions at the time of the monthly peak
  - Assign the maximum temperature to the two assigned peak days for that month. These days will be 3 days apart. This ensures that peak weather conditions occur on a weekday

Minimum Temperature Forecast
Winter Months
Process Details

Minimum Temperature Forecast for the Winter Months

- **For January through March and December**
  - Process is very similar to the one used to determine the other summer months’ maximum temperatures
  - The only difference is that the minimum temperatures are used instead of maximum temperatures for the individual month

- **Winter Months Minimum Temperature Forecast**
  - Determine the annual minimum temperature for the individual month
  - Calculate the 15-year average minimum temperature
  - Select the weather data for the minimum temperature day from the year which has the closest temperature that is less than or equal to the average
  - The day containing the minimum temperature and the preceding day will be used to represent the weather conditions at the time of the monthly peak
  - Assign the minimum temperature to the two assigned peak days for that month. These days will be 3 days apart. This ensures that peak weather conditions occur on a weekday

ERCOT Weather Assumptions

Weather Assumptions ERCOT-wide

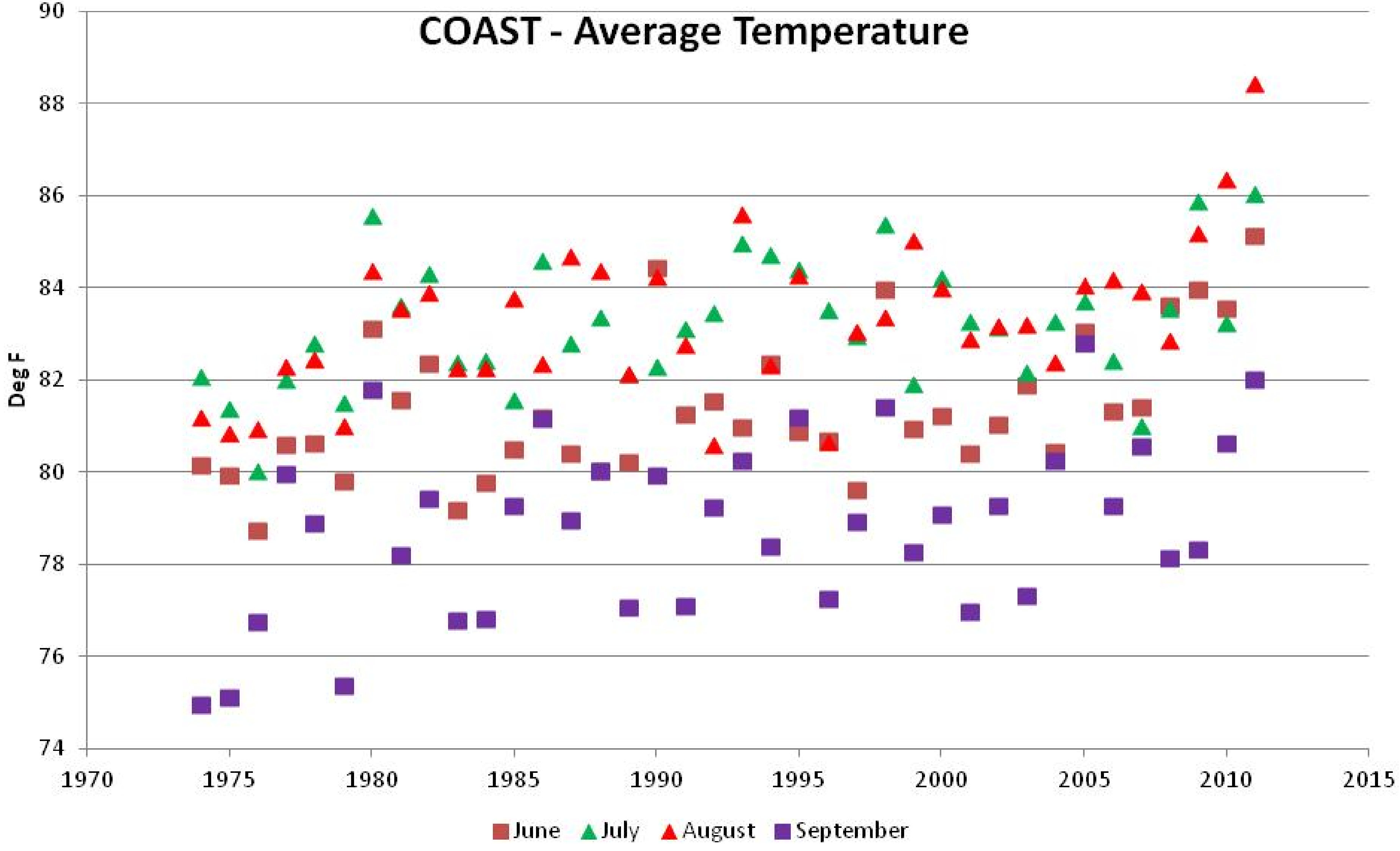
- **ERCOT represents a large geographical area making the derivation of a “normal” year complicated**
  - Should consistent weather data (i.e., same historical month) be used for all weather zones?
  - Should different weather data (i.e., may use historical months from different years) be used for weather zones?
- **ERCOT uses the best fitting historical weather data for each weather zone.**
  - Weather data from different years can be used for each weather zone

- **Using different historical years will likely create peak demand forecasts which are too low based on a higher than normal coincidence factor**
  - Example, August 2001 data is used for NCENT weather zone with very hot temperatures during the first week of the month
  - August 2008 data is used for COAST with the last week of the month being very hot
  - This will result in a smaller coincidence factor between the peak loads of these weather zones than is normally observed during the summer peak

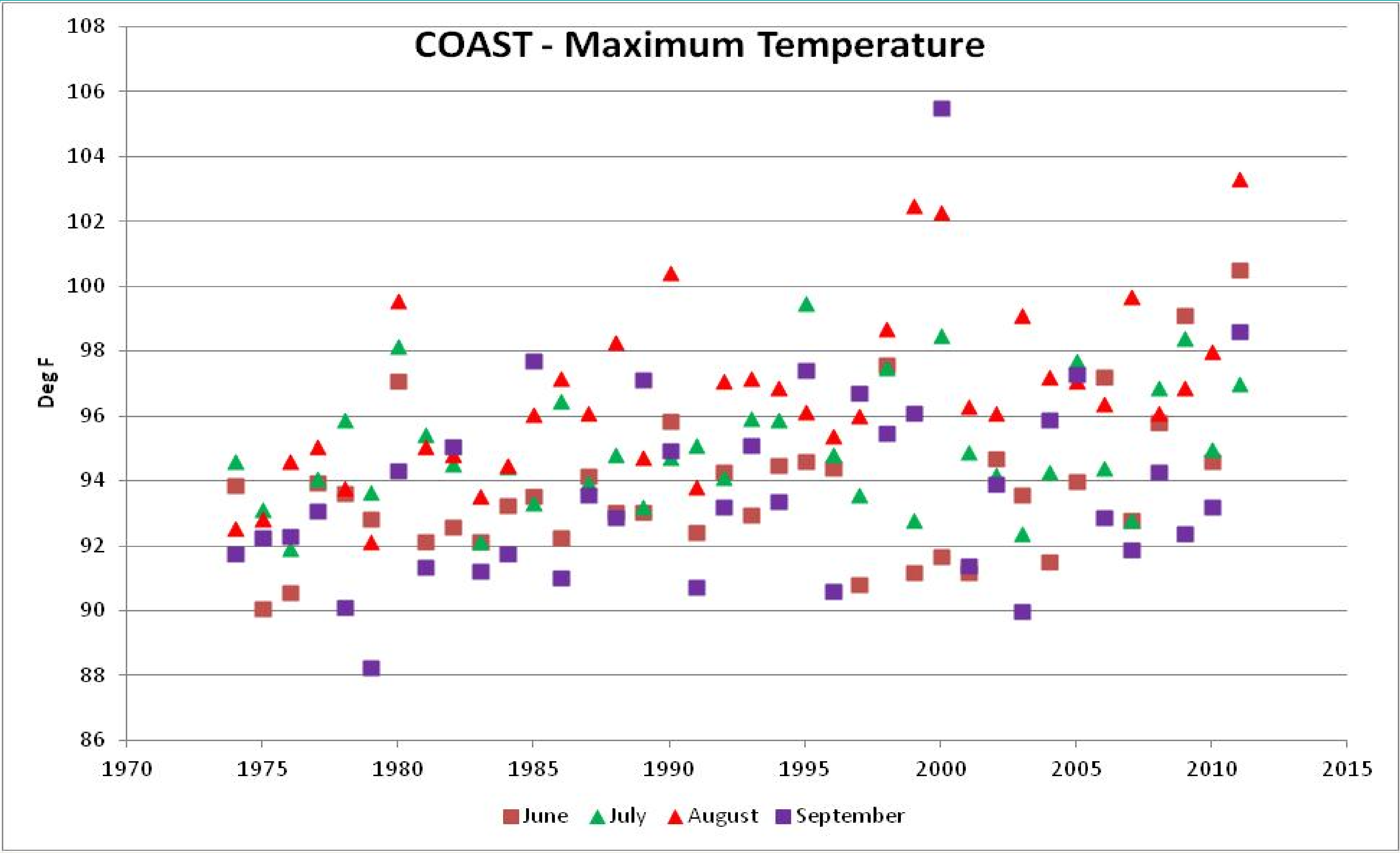
- **To correct for this problem, monthly peak days are assigned**

ERCOT Weather Trends

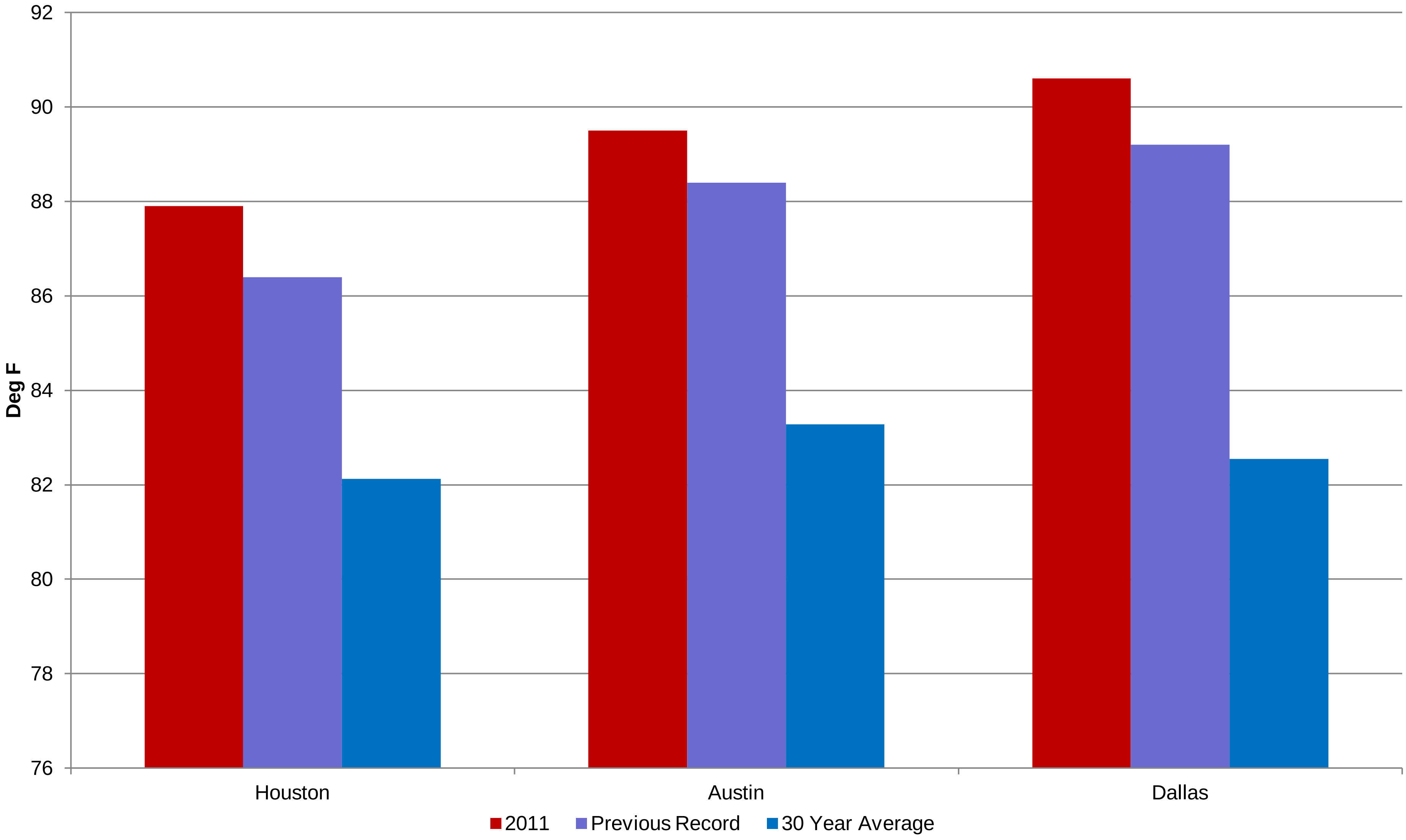
Weather Trends

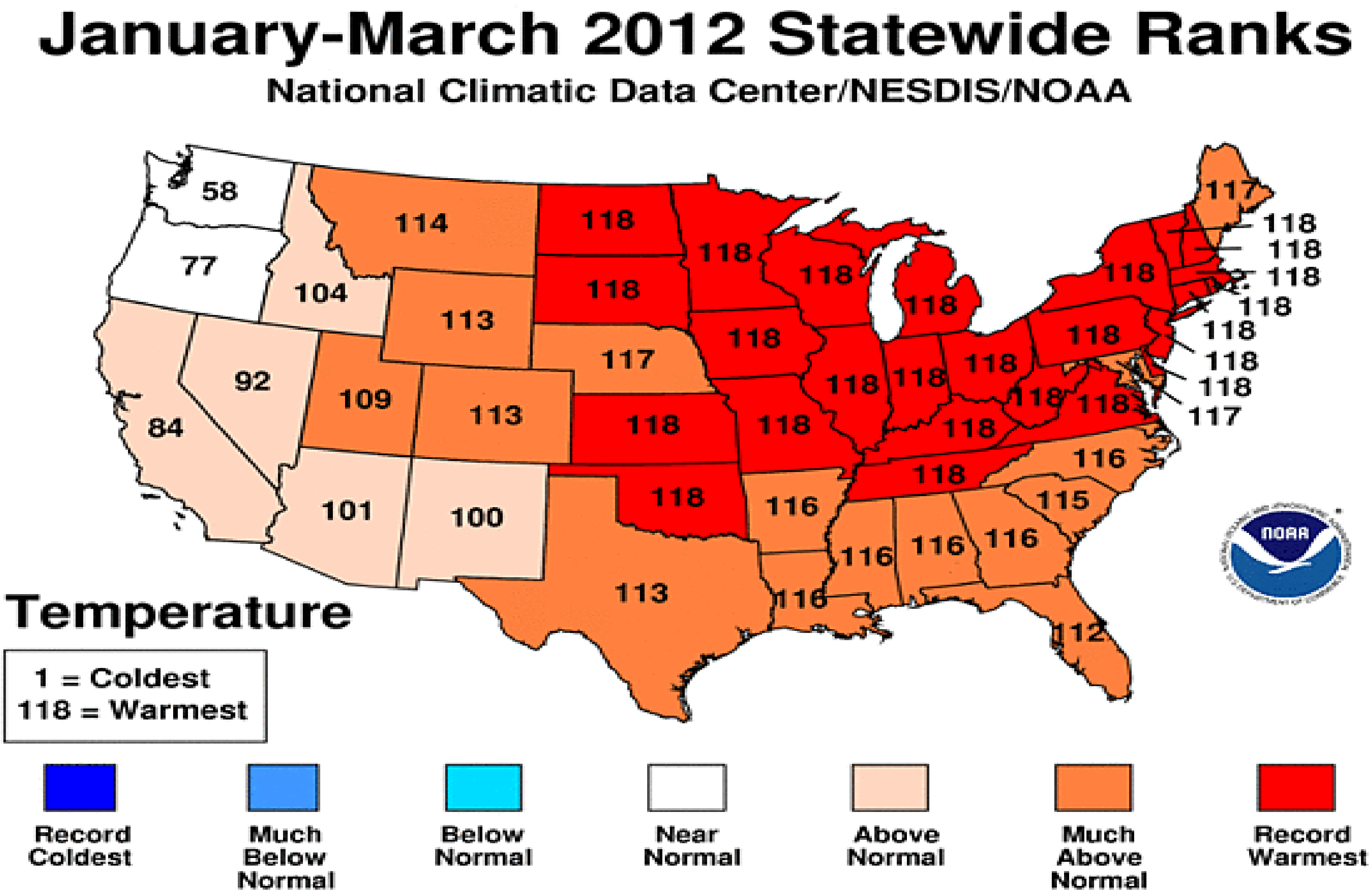


Weather Trends

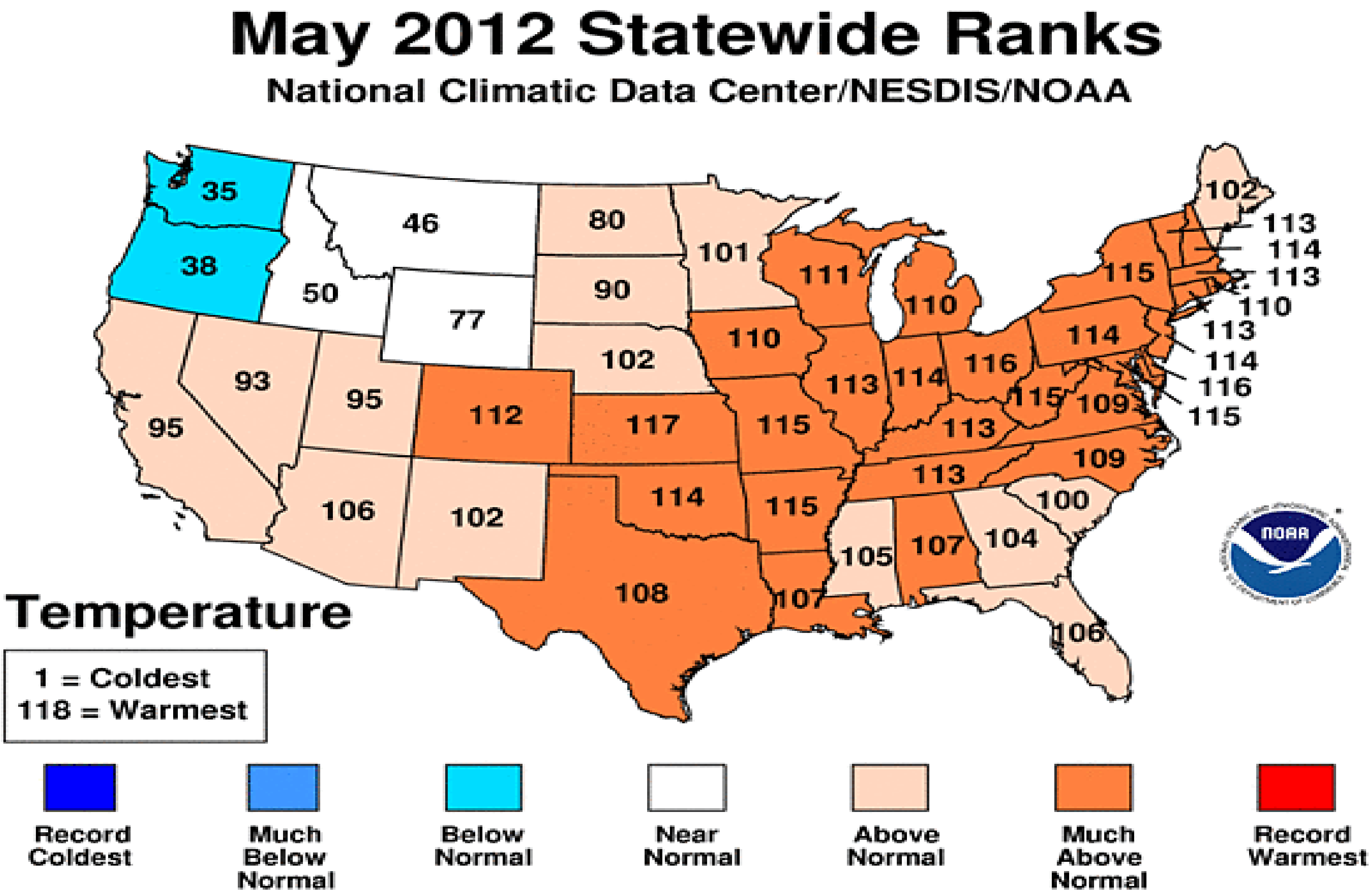


Average Summer Temperature (June – August)





January-March 2012 Statewide Ranks
National Climatic Data Center/NESDIS/NOAA
Temperature
1 = Coldest
118 = Warmest
Record Coldest
Much Below Normal
Below Normal
Near Normal
Above Normal
Much Above Normal
Record Warmest


May 2012 Statewide Ranks
National Climatic Data Center/NESDIS/NOAA
35
38
46
50
77
80
90
101
102
93
95
95
112
117
110
111
110
113
114
116
115
114
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113
109
100
104
107
105
107
106
102
106
114
115
108
Temperature
1 = Coldest
118 = Warmest
Record Coldest
Much Below Normal
Below Normal
Near Normal
Above Normal
Much Above Normal
Record Warmest

Weather Assumptions - Challenges

- **Will the current trend of increasing monthly average temperatures and monthly maximum temperatures continue?**
- **Will the current cycle of extreme weather continue?**
- **Is the distribution of monthly average temperatures still approximately normal?**
- **Is the distribution of monthly maximum temperatures still approximately normal?**
- **Investigate using alternative derivations of “normal” weather**

Forecast Model Description

Long-Term Load Forecast Model Description

- **Independent models are created for each of ERCOT's eight weather zones**

- **Two sets of models are used to create the long-term load forecast**

  - Monthly energy models

  - Hourly energy models

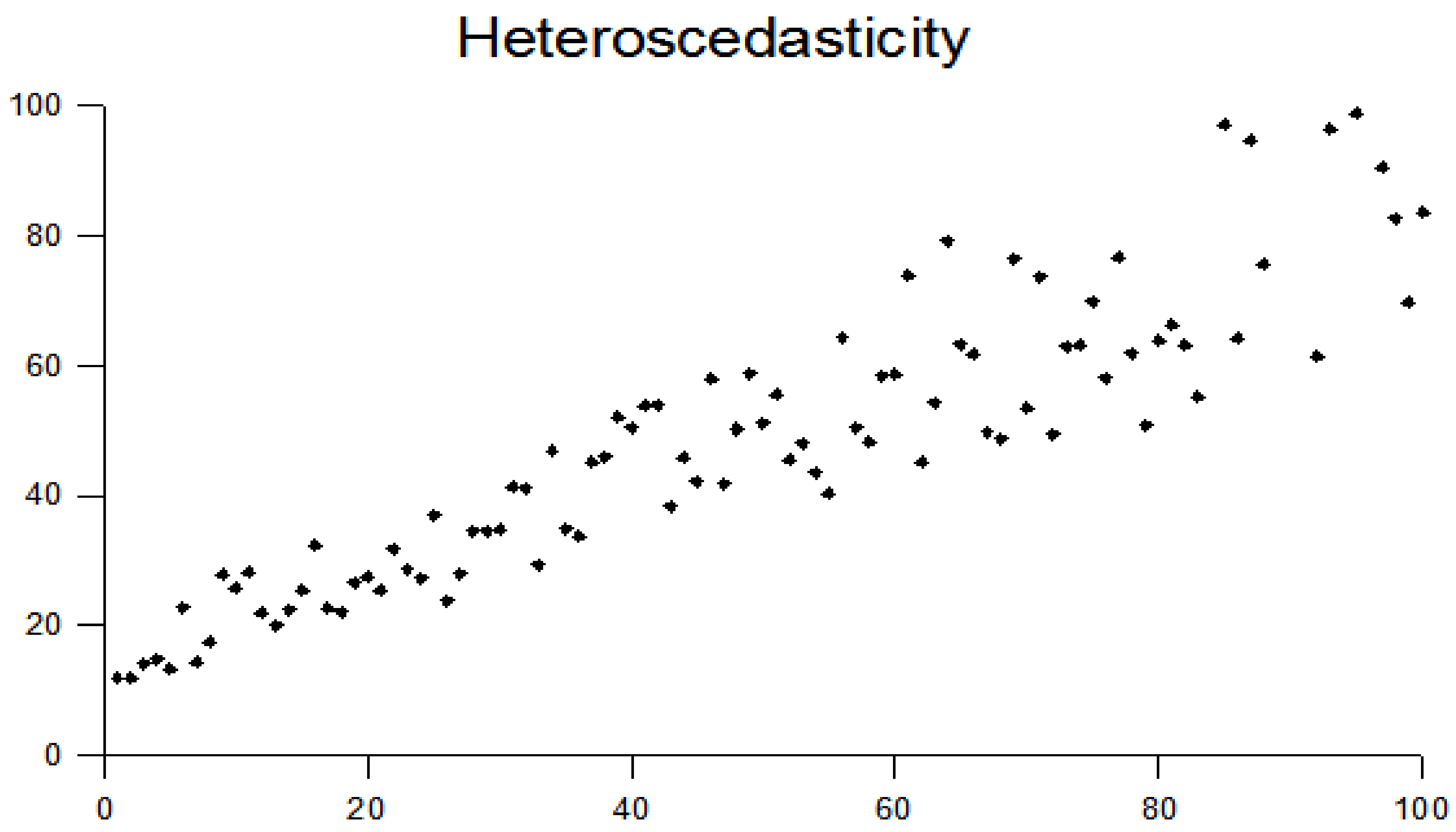
- **Monthly energy models**
  - Creates a total energy forecast for each weather zone, for each month in the forecast time period
  - Long-term growth in energy consumption is correlated with non-farm employment forecast
  - The same weather is used for each forecast year

- **Hourly energy model**
  - Allocates energy from the monthly energy forecast to each hour within the month for each weather zone

Monthly Energy Model Description

- **A two season model is used (summer and winter)**
  - April through September are assigned to the summer season
  - November, December, January, February, and March are assigned to the winter season
- **Each weather zone model forecasts monthly MWh per one thousand non-farm jobs per day**
- **Multiplying this result by the number of days in the month gives the monthly total energy for the weather zone**
- **Selected this modeling approach due to concerns of heteroscedasticity**

Heteroscedasticity Example



Monthly Energy Model Description

- **Monthly MWh per one thousand non-farm jobs per day is estimated using a model that has weather data (i.e., cooling degree days and heating degree days) as independent variables**

- **Degree days (cooling and heating) for the month are divided by the days in the month which results in a degree day per day variable representation which is used in the model**

- **This approach eliminates the need for “dummy” variables (typically used for months like February, April, June, September, and November which have fewer days)**

Monthly Energy Model Description

- **Monthly energy model examples:**

- **(Daily Energy $_{COAST}$) / Non-Farm Employment $_{COAST}$ =**

  75.87 + 1.54 HDD_{50} per day + 0.37 HDD_{65} per day + 1.53 CDD_{65} per day

  - this model uses Heating Degree Days with bases of 50 and 65
  - this model uses Cooling Degree Days with a base of 65
  - this model is for the winter season

- **(Daily Energy $_{NCENT}$) / Non-Farm Employment $_{NCENT}$ =**

  66.51 + 2.33 CDD_{65} per day + 0.81 CDD_{85} per day

  - this model uses Cooling Degree Days with bases of 65 and 85
  - this model is for the summer season

Hourly Energy Model Description

- **A neural network model was developed for each weather zone, for each day type, for each hour that forecasts the hourly fraction of energy for each hour within a month**

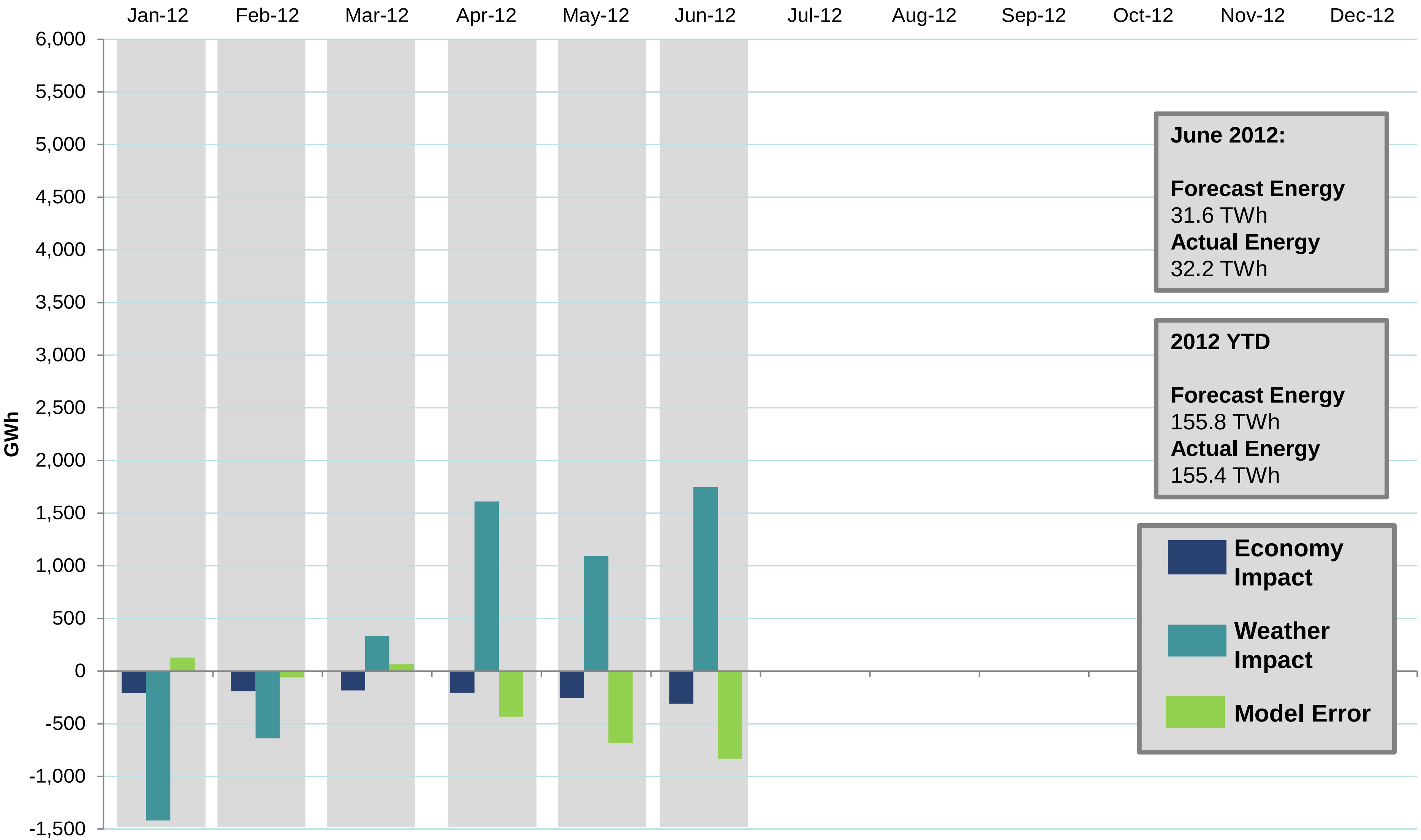
- **The neural network model is based on the following variables:**
  – Sunset time
  – Current day's maximum and minimum temperatures
  – Previous day's maximum and minimum temperatures
  – Current day's temperatures at 7 a.m., noon, and 7 p.m.
  – Hourly fraction of the prior hour
  – Average monthly temperature

Hourly Energy Model Description

- **Day types are Saturday, Sunday or holidays, and weekdays excluding holidays**
- **Multiplying the weather zone's hourly fraction by the weather zone's total energy for the month produces the hourly energy forecast for each Weather Zone**
- **The monthly peaks for the eight weather zones are time-aligned**
- **The eight weather zone forecasts are summed to create the ERCOT hourly load forecast**

Forecast Model Results

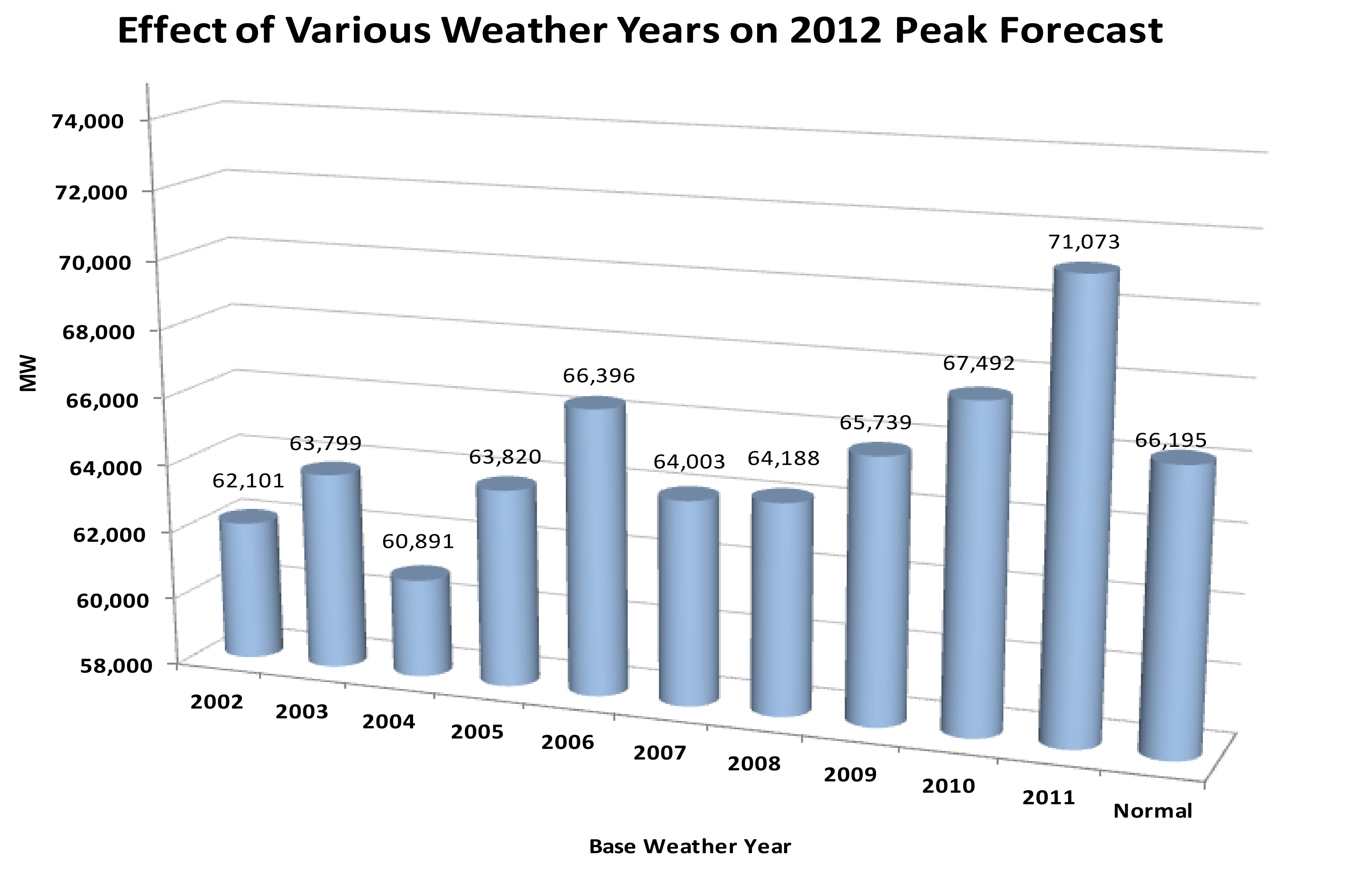
Impacts of Economy & Weather as Compared to Forecast



Forecasting Results

- **Developed weather scenarios by using actual weather data for 1997 through 2011**
  - Used the actual weather data for a historical year as the forecasted weather for all years in the forecast timeframe
  - This resulted in fifteen distinct scenarios
- **Used Moody's base case economic forecast for these scenarios**

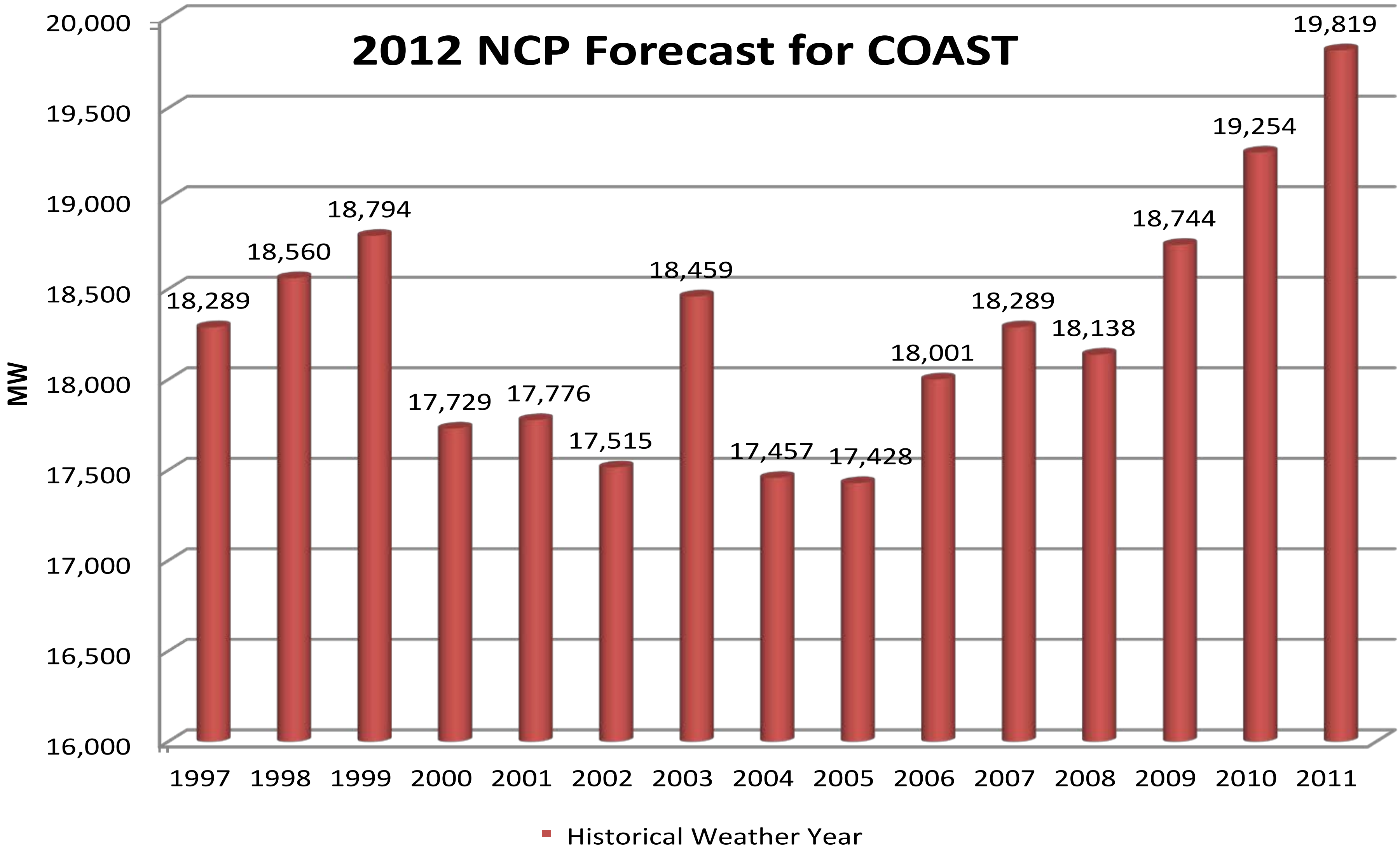
2012 ERCOT Summer Forecasted Peak Demand Sensitivities



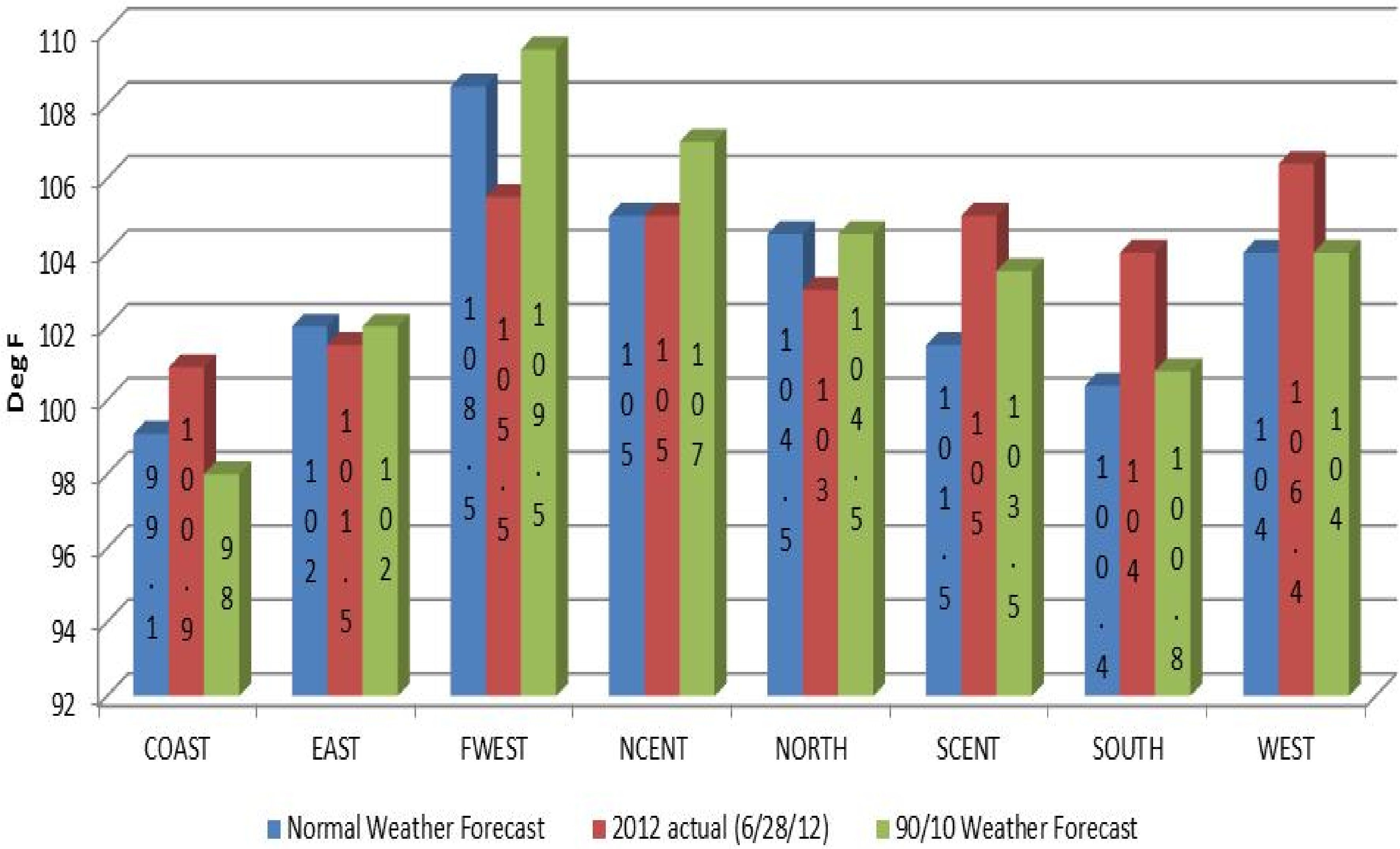
- **Developed the 90/10 non-coincident peak (by weather zone) forecast by using actual weather data for 1997 through 2011**

- **For each weather zone:**
  - The maximum summer non-coincident peak was calculated for the target forecast year using the 15 years of actual weather data
  - The non-coincident peaks were then ordered from smallest to largest
  - The second largest value was used as the 90/10 non-coincident peak forecast

2012 COAST Summer Forecasted NCP Sensitivities



90/10 Weather Forecast



Future Enhancements

Adjustments to the Long-Term Forecast

- **No significant incremental changes have been reflected in the long-term forecast to account for:**
  - Energy Efficiency
  - Demand Response
  - Distributed Generation
  - Plug-in Electric Vehicles
  - Energy Storage
- **These will need to be developed in the future**

2012 Enhancements

- **Changes coming this year**
  - Forecast Model is being changed to a daily energy model
  - Energy Efficiency forecast scenarios will be created by ERCOT using a newly developed in-house model.
    - We will still also create an energy efficiency forecast which ties to approved regulatory filings

Longer-Term Enhancements

- **Additional Enhancements**
  - Publish supplemental data used in the load forecast(s) on either MIS or POI website
    - Would include weather data, employment data, presentations, documentation, etc.
    - Could include SARA forecast, 90/10 forecast, etc.
    - Need input as to which location is preferred.
- **Develop a load forecast model that is based on customer classifications (residential, commercial, industrial)**
  - Would use existing ESIID load profiles
  - For NOIEs, models would be developed for their total load

Questions