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THE EASTERN UNITED STATES HEAT WAVE OF 3-8 JULY 2010

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1. INTRODUCTION

A sustained heat wave affected the eastern United States from 3-8 July 2010. This event shared all the common characteristics of previously documented heat waves (Lipton et al. 2005) including a large subtropical ridge with a closed 5940 m contour at times, above normal 850 and 700 hPa temperatures and a surge of deep moisture north and west of the heat-affected region. The event set many new high temperature records (Table 1) from New England to North Carolina with 45 airport locations reaching or exceeding 37.8 °C (100 °F) on the 6 July 2010.

There are varying definitions of a heat wave (Robinson 2001). Several definitions require the duration of above normal conditions for 2-3 days. Others focus on high temperatures of approximately two standard deviations (SDs) above normal for about two days over a region rather than single stations. Robinson also describes a definition of a heat wave "as period of at least 48 h during which neither the overnight low nor the daytime high value of the heat index falls below 26.7 °C (80 °F) and 40.6 °C (105 °F), respectively." An early 20th century definition required 3 consecutive days of 32.2 °C (90 °F) temperature observations, which is the generally accepted definition for a heat wave and is used in this paper.

Heat waves are one of the most significant causes of weather related fatalities. Changnon et al. (1996) documented the 1995 Midwestern United States heat wave, which caused 525 deaths in Chicago and 830 deaths nationwide. Contributing factors related to the deaths in Chicago included the high dew points, the urban heat island effects, the aging population, and the lack of ventilation. Kunkel et al. (1996) attributed two essential factors to the fatal affects of the heat wave including the high dew points and the urban heat island effects. The large number of deaths due to the 2003 European heat wave in France and Italy may have been related to population demographics and a lack of the wide use of air conditioning.

The heat wave of July 1999 caused an estimated 309 deaths in 21 States, with the majority (258) of the deaths occurring in the midwestern United States in late July (Palecki et al. 2001). The July 1999 event was of longer duration than the July 1995 event but it did not achieve the intensity of the 1995 event. The apparent temperatures during the July 1999 event were lower than in the July 1995 event due to lower moisture values.

Heat waves are not unique to the United States. Deadly heat waves impacted Europe in the summers of 2003 and 2006*. The 2003 heat wave was responsible for around 35,000 deaths (Schär and Jendritzky 2004). The conditions associated with the European heat waves of 1906, 1911, and 1990 that affected the United Kingdom were studied by Brugge (1991). The favored period for persistent heat waves appeared to be late July and early August. The synoptic scale pattern requires cloud free, anticyclonic conditions. In the United Kingdom, low-level southeasterly flow off the continent is another important factor in achieving high temperatures. Antecedent drought conditions also appear important in the more intense heat waves. The United States heat wave of 1988 may have shared a similar antecedent drought scenario.

Namias (1982) showed that heat waves in the United States are characterized by strong subtropical ridges. Prolonged and damaging heat waves in the United States are also associated with ridges over the oceans. The association of anticyclones with United States and United Kingdom heat waves appears both to be a common thread. The subsidence produces cloud free conditions and a subsidence inversion (Brugge 1991) which facilitate the development and maintenance of the low-level heat. The basic characteristics of mid-latitude heat waves in the United States and Europe may contain several similar characteristics. Research on European heat waves show a similar dependence on a strong subtropical ridge in producing the long-lived events with record high temperatures. Livezey and Tinker (1996) documented the importance of the strong and persistent anticyclonic conditions which persisted over the Midwest during the fatal 1995 Chicago heat wave.

From a forecast perspective, the scenarios outlined by Namias (1982) and Brugge (1991) suggest a large subtropical ridge as a key ingredient in most heat waves. The intensity of these ridges can be identified using normalized climatic anomalies (Hart and Grumm 2001). Lipton et al. (2005) showed the anomalies of 500 hPa heights, 850 and 700 hPa temperatures, and 1000-500 hPa thickness for heat waves over the Mid-Atlantic region

* NCDC climate hazards and extremes web page referenced the mid-late July 2006 European heat wave. New all-time high in UK on the afternoon of July 19th where temperature reached 36.3°C (97.3°F) at Charlwood.

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from 1948-1999. These analyses also showed the role of moisture, as shown by precipitable water anomalies in several of the heat waves.

This paper will examine the conditions associated the early season heat wave of 3-8 July 2010. The focus is on the value of climatic anomalies to predict and characterize the heat wave. Data from previous heat waves, as analyzed by the National Centers for Environmental Prediction (NCEP) Global Reanalysis (GR) data, are also presented. The focus is on the traditional features used to identify heat waves including 500 hPa heights, 925 and 850 hPa temperatures and their departures from normal (climatic anomalies). Precipitable water (PW) anomalies are shown as additional tools to characterize a heat wave. Model data from the NCEP Global Forecast System (GFS) and Global Ensemble Forecast System (GEFS) are shown to demonstrate how the key variables can be used to predict significant heat waves in advance.

2. METHODS AND DATA

High temperature observations were extracted from the web[*] in near-real time to evaluate the event and track the observed high temperatures at synoptic sites. Pennsylvania data were retrieved from the local National Weather Service (NWS) Cooperative Observing Program (COOP) data base. Model data used in the analysis included the NCEP Global Forecast System (GFS), which was used to show the evolution of the case. However, the Japanese Reanalysis (JRA) data was used to compare key heat wave characteristics for comparison to a 1999 heat wave. In this paper, the focus is on 00-hour forecasts showing the general evolution of the event. The 00-hour forecast fields were displayed showing departures from normal relative the 30-year mean and standard deviations derived from the NCEP GR data as presented in Hart and Grumm (2001) and Lipton et al. (2005). All times are in the format 06/0000 UTC implying 0000 UTC 6 July 2010. Most images are from 0000 UTC as this is closest to the time of maximum heating.

The GR means and standard deviations span the 30-year period of 1970-2000. Archives of all GR data span 1948-2006, allowing the extraction of the conditions associated with previously documented heat waves. For illustrative purposes, previous heat wave cases are displayed using these data.

3. RESULTS

3.1 *Overview of the Pattern*

The large scale pattern depicted an ideal setup for an extended heat wave, *i) the strong subtropical ridge at 500 hPa (Fig. 1), ii) the surge of high PW air north and west of the subtropical ridge (Fig. 2), and iii) the deep warm air (Figs. 3-5)* associated with the heat wave.

[*] The Pennsylvania State University site at: http://www.meteo.psu.edu/~gadomski/MAXMIN_NA/naloop8.html

The 500 hPa height anomalies were +1 to +2 Standard Deviations (SDs) above normal by 03/1800 UTC over the eastern United States (Fig. 1b) and increased to over +3 SDs above normal on 5-6 July (Figs. 1g-i).

The GFS PW and PW anomalies (Fig. 2) showed the initially dry air over eastern North America. As the ridge strengthened, there was a surge of warm moist air around the western edge of the subtropical ridge (Figs. 2a-i). PW anomalies in excess of +4 SDs above normal were well into Ontario by 04/1800 UTC. The classic surge of moisture around the ridge was clearly established by this time.

At 700 hPa (Fig. 3) a pocket of anomalous +1 to +3 SD temperatures was present over the plains of North America (Fig. 3a) which moved eastward with the subtropical ridge. This pocket of warm air moved over the Great Lakes and into the eastern United States from 04/1800 UTC through 05/1800 UTC, coinciding with surface temperatures exceeding 32.2 °C (90 °F) in the northeastern United States and a few readings over 37.8 °C (100 °F), especially in the New York City Metropolitan area.

By 06/0000 UTC the deep warm air mass was entrenched over the entire eastern United States with +1 to 3 SD 700 hPa temperatures. This pattern produced 45 readings of 37.8 °C (100 °F) or greater on the 6 July 2010 (Table 2 and Fig. 6). A west-northwesterly low-level flow (not shown) likely contributed to the heat on this day due to the combination of adiabatic warming, and also by preventing the typical inland penetration of the cooling sea breeze.

Figure 7 shows the 500 hPa pattern for the period of 07/1800 UTC to 10/0000 UTC. The upper-level closed anticyclone and cut-off low under the larger scale ridge both retrograded westward. The easterly flow with the low provided some relief of New England and eastern Long Island. The ridge continued to weaken and the easterly flow moved farther west, cooling many locations in the eastern United States on 8 July 2010. The 500 hPa pattern showed a trough moving into the eastern United States by 09/1800 UTC, and the traditional heat wave pattern was no longer visible by 10/0000 UTC. This event clearly ended on 9 July 2010 for nearly all locations.

The PW and PW anomalies for the second part of the heat wave are shown in Figure 8. These data show the surge of +1 to +2 PW anomalies with the upper-level low over the western Atlantic. Areas affected by this influx of higher PW saw a marked decrease in daily high temperatures. This boundary delineated a maritime air mass (Figs. 8a-d) which eventually pushed westward into Pennsylvania (Fig. 8d). The high PW air to the west, which was moving eastward, suggested a progressive pattern and this region of high PW air brought rain from west to east across the eastern United States from 9-10 July, ending the heat wave from west to east. Cooler and drier weather moved in behind this system (not shown).

The warmest temperatures at 700 hPa (Fig. 9) and 850 hPa (Fig. 10) showed a similar westward shift over time. The 850 hPa temperatures (Fig. 10) showed the 20 °C contour and +2 to +3 SD anomaly region over New England (Fig. 6a) weaken in northern areas and shift westward after 08/0000 UTC (Figs 10b-c). The pocket of warmest air drifted southward and was over South Carolina (Figs. 10d-f) and Georgia by 09/1800 UTC. The evolution of the 850 hPa temperatures mirrored the shift in the 500 hPa pattern (Fig. 7).

3.2 *Observations*

Figure 6 shows areas in the eastern United States where high temperatures reached or exceeded 37.8 °C (100 °F) on 6 July 2010. These hot temperatures from New England to North Carolina were in close proximity and mainly east of the subtropical ridge (Fig. 1) along the edge of the 5940 m closed contour observed at both 06/1800 and 07/0000 UTC (Figs. 1h-i). These record and near record high temperatures were also beneath the 925 hPa +28 °C temperature contour (Fig. 4) and the 850 hPa +20 °C temperature contour (Fig. 5), and in close proximity to the warmest air at 700 hPa. The strong subsidence implied a deep warm boundary layer.

The high temperatures on 6 July exceeded 32.2 °C (90 °F) from Maine to North Carolina (Table 1) and over 37.8 °C (100 °F) along the coast (Table 2 & Fig. 6). Many of the record high temperatures which fell on 6 July 2010 were set back in the heat wave of 1999. The hottest day of the 4-6 July 1999 at most locations was 6 July with many daily maximum temperatures exceeding 37.8 °C (100 °F). There were many readings in the 90s on 6 July 2010 and few 100+ readings before a cold front ended the event. Figure 11 shows the pattern over the northeastern United States at 05/1800 UTC July 1999, using the Japanese Reanalysis (JRA) data. The 1999 heat wave also shared the common characteristics of most record warm events in the eastern United States, including anomalous 500 hPa heights with a closed 5940 m contour, deep warm air, and an anomalous surge of high precipitable water to the north and west of the heat affected region.

The data in Tables 1 & 2 imply that 6-7 July 2010 (Tuesday and Wednesday) were the hottest days of the event having the most 37.8 °C (100 °F) or warmer daily maximum temperatures.

3.3 *Forecasts*

The GEFS, as shown in Figure 12, indicated the potential for an extended period of heat at least 5 days of the onset of the heat wave. Although the magnitudes of key predictors at this time range were less extreme, they still exhibited characteristics capable of producing an extended period of heat, including anomalously high 500 hPa heights and 850 hPa temperatures for 5-6 July. As the event neared, these values and anomalies in the GEFS increased further (not shown), increasing forecaster confidence that the potential for an extended period of heat would occur. This also allowed forecasters to communicate this potential to emergency managers and the public, allowing for early preparations to mitigate potential heat-related consequences.

4. SUMMARY

A heat wave affected the eastern United States from 3-8 July 2010 based on the definition of daily maximum temperatures reaching or exceeding 32.2 °C (90 °F) for at least 3 consecutive days.

The characteristics of heat waves over North America are relatively well known. These characteristics can be used to identify key predictors. These predictors include 925, 850 and 700 hPa temperatures and temperature anomalies, 500 hPa heights and precipitable water anomalies.

The 3-8 July 2010 heat wave demonstrated some of the key fields often used to identify and track heat waves. The emphasis here was on the 500 hPa heights associated with the ridge, and the anomalous temperatures at 925, 850 and 700 hPa.

The large-scale conditions associated with this heat wave were similar to those associated with previous heat events, including a large subtropical ridge with anomalous 500 hPa heights. At lower levels, 850 and 925 hPa temperature anomalies were associated with regions of extreme heat where surface temperatures exceeded 32.2 °C (90 °F). In addition, anomalously warm temperatures at 700 hPa occurred over the heat affected region, likely limiting convective potential and cloud cover.

A surge of above normal PW north and west of the subtropical ridge is also a common trait associated with a pronounced heat wave. This event had this classic signature with the surge of anomalous PW north and west of the subtropical ridge and area of highest surface temperatures. This surge of anomalously high PW's likely contributed to the heavy rains observed in upper midwest during the heat wave.

The GEFS was able to forecast this heat wave with some degree of accuracy several days in advance. Forecast predictors increased in value as the event neared, further allowing forecasters to gain confidence in the occurrence of a major heat wave and to convey the impending threats from an extended period of heat to emergency management officials and the public days in advance.

All heat waves share common characteristics, though each has some unique attributes. Some are more enduring, like the 1988 event, where high temperatures persist for over a week. Others set many high temperature records. This event appeared to endure for about 4-6 days depending upon the location. This event peaked in the eastern United States on 6 July when 45 major airport sites reached or exceed 37.8 °C (100 °F). The data in Table 3 suggests 2, 10, 45, 30, and 2 sites reached or exceed 37.8 °C (100 °F) on 4, 5, 6, 7, and 8 July respectively. The data in Table 3 suggest that the event peaked on the 6th although many sites were 90 or greater from the 4-7 July 2010. The cut-off low which drifted westward as the upper-level ridge retrograded contributed markedly to the decrease expanse of the warm air.

5. ACKNOWLEDGEMENTS

A special thanks to Michael Kozar and Jason Krekeler for data extraction and tabulation for the Tables herein. This included checking NWS Public Information Statements (PNS's). All NWS offices for collecting and processing data for record events. Finally, a thanks to Dr. Robert Hart (Florida State University) for the map of METAR sites reaching or exceeding 37.8 °C (100 °F) on 6 July 2010.

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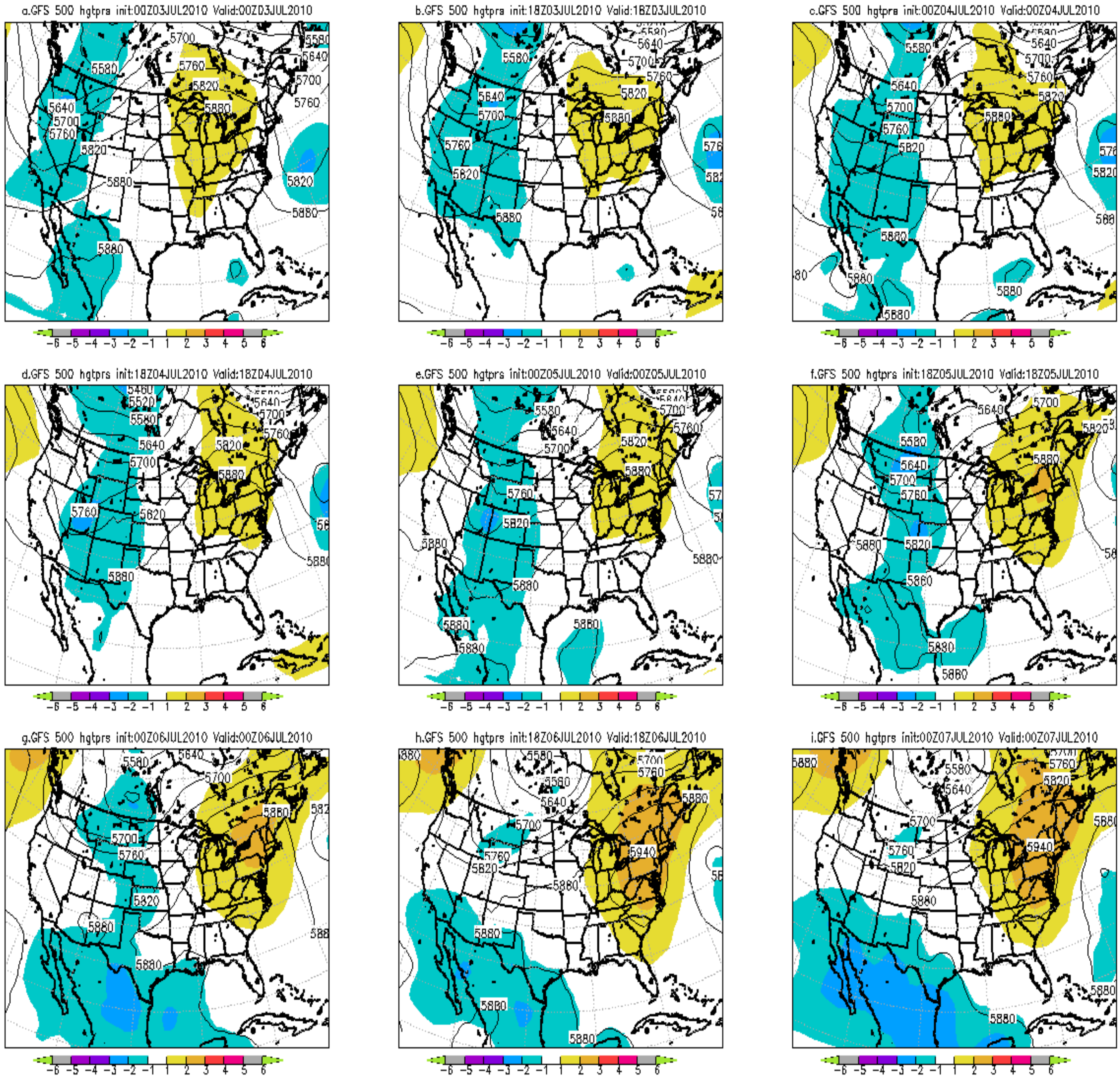

Figure 1. GFS 00-hour forecast of 500 hPa heights and height anomalies valid from a) 0000 UTC 03 July, b) 1800 UTC 03 July, c) 0000 UTC 04 July, d) 1800 UTC 04 July, e) 0000 UTC 05 July, f) 1800 UTC 05 July, g) 0000 UTC 06 July, h) 1800 UTC 06 July and i) 0000 UTC 07 July 2010. Heights in meters every 60 m and anomalies in standard deviations from normal.

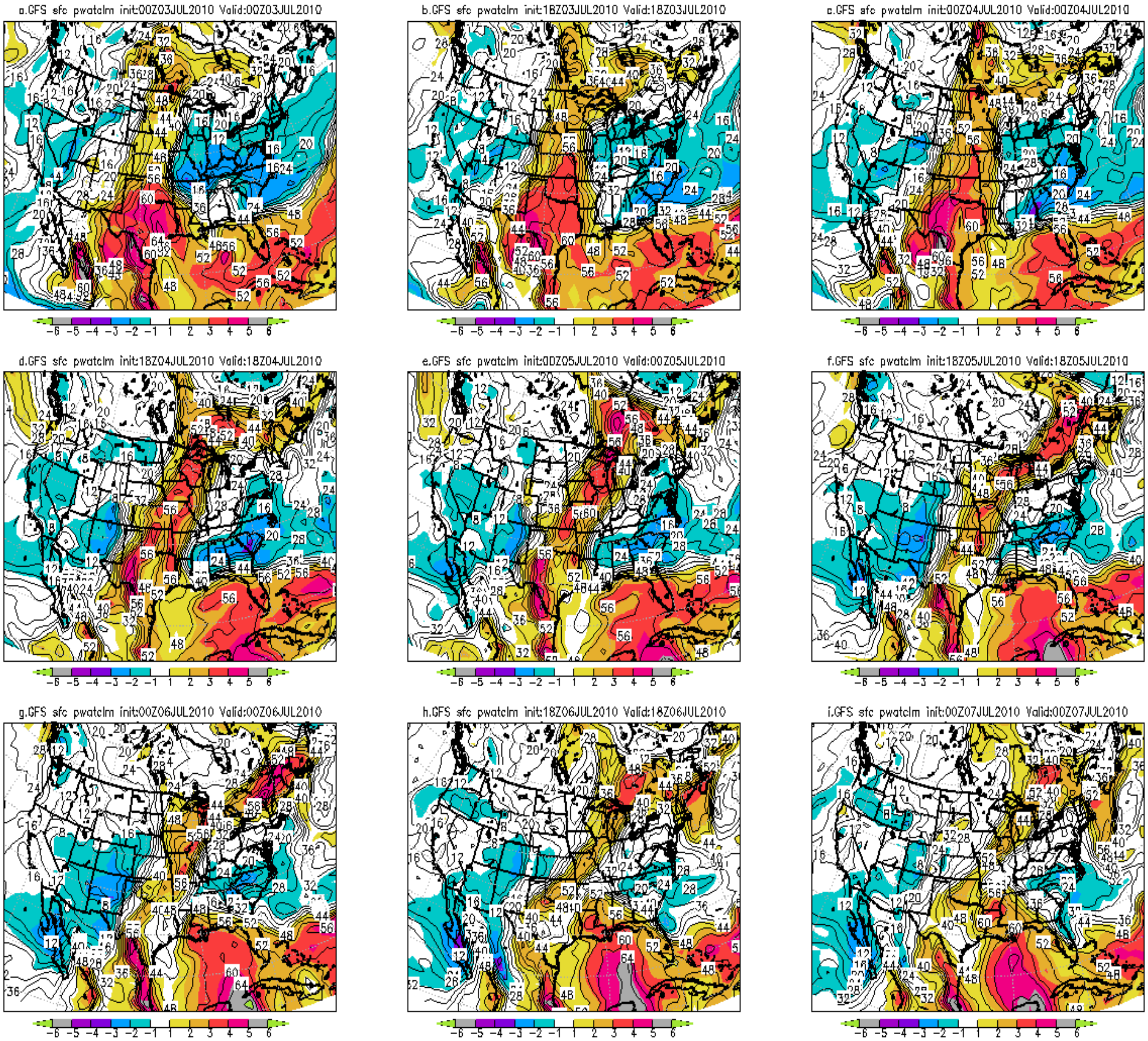

Figure 2. As in Figure 1 except for precipitable water (mm) and precipitable water anomalies.

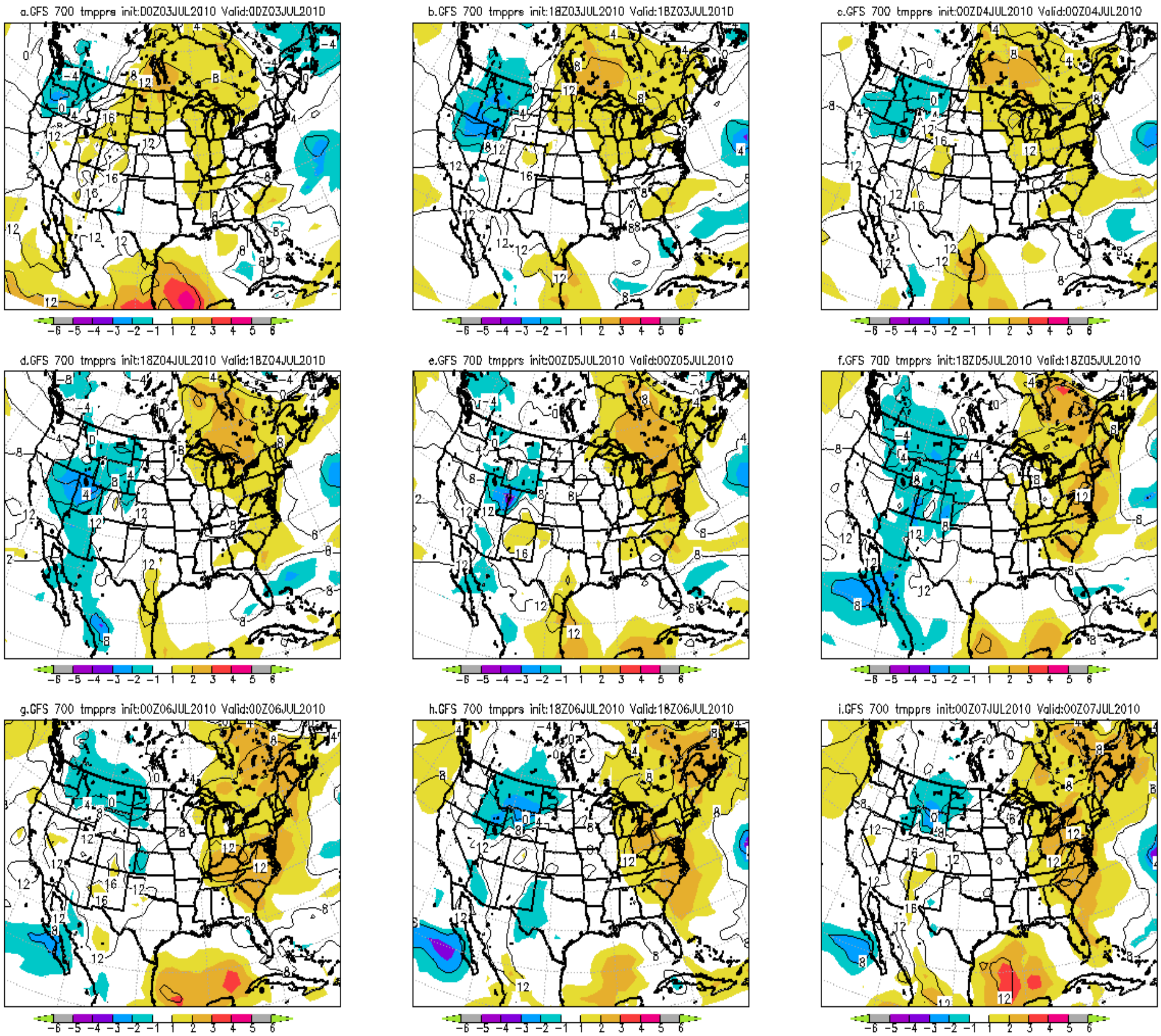

Figure 3. GFS 00-hour forecast of 700 hPa temperature and temperature anomalies valid from a) 0000 UTC 03 July, b) 1800 UTC 03 July, c) 0000 UTC 04 July, d) 1800 UTC 04 July, e) 0000 UTC 05 July, f) 1800 UTC 05 July, g) 0000 UTC 06 July, h) 1800 UTC 06 July, i) 0000 UTC 07 July 2010. Temperatures in °C and anomalies in standard deviations from normal.

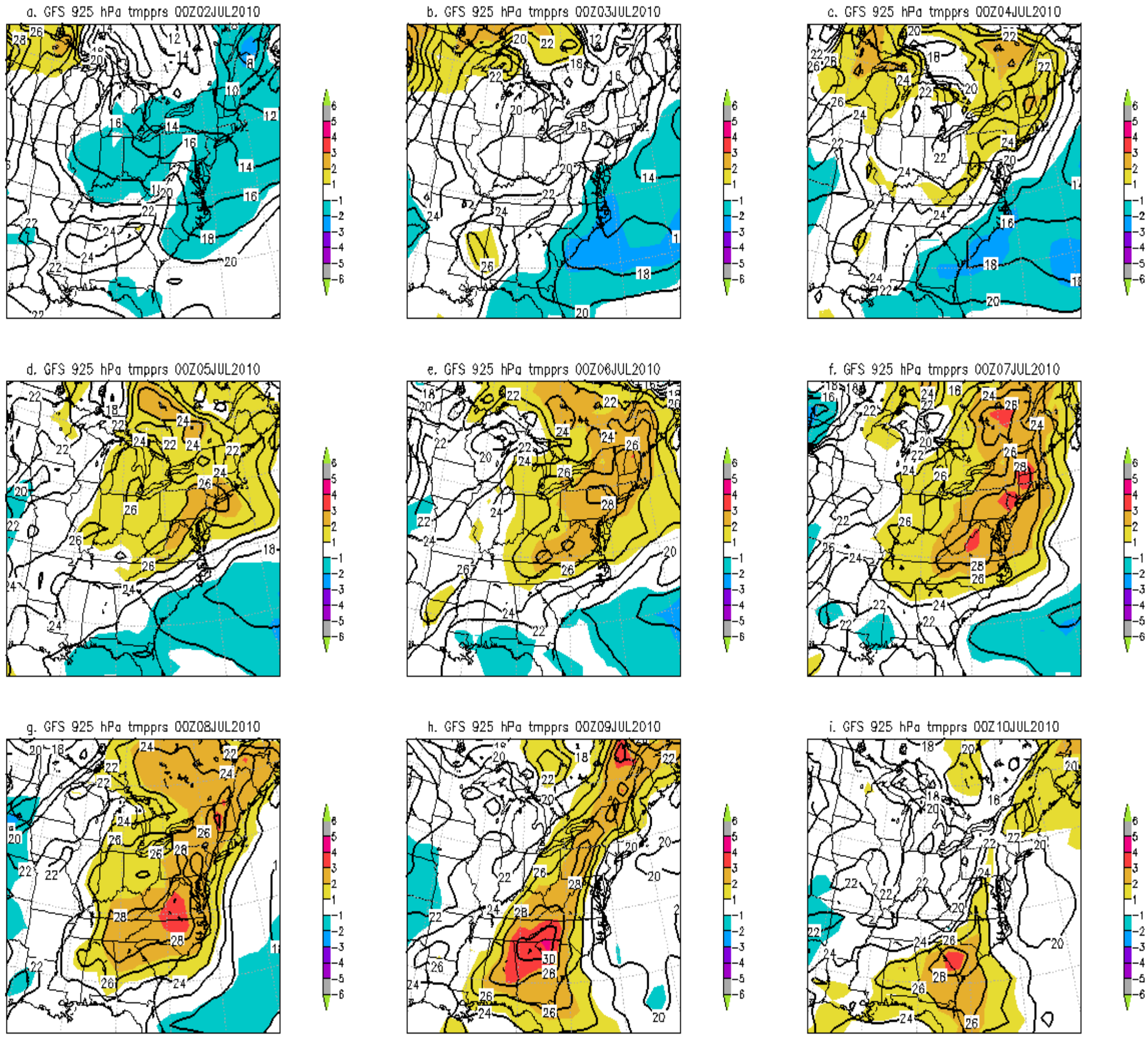

Figure 4. GFS 00-hour forecast of 925 hPa temperatures and temperature anomalies valid from a) 0000 UTC 02 July, b) 0000 UTC 03 July, c) 0000 UTC 04 July, d) 0000 UTC 05 July, e) 0000 UTC 06 July, f) 0000 UTC 07 July, g) 0000 UTC 08 July, h) 0000 UTC 09 July, i) 0000 UTC 10 July 2010. Temperatures in °C and anomalies in standard deviations from normal.

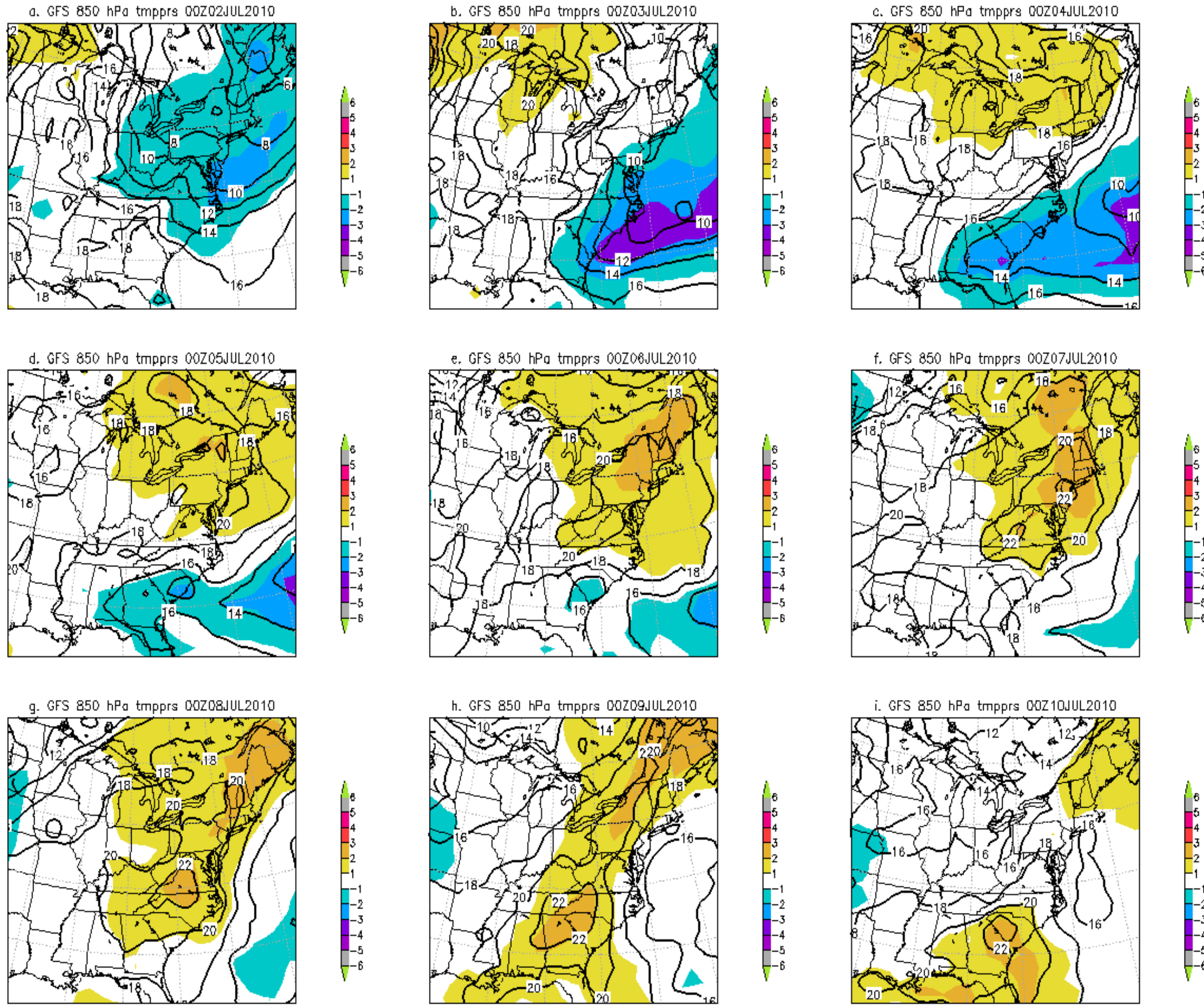

Figure 5. GFS 00-hour forecast of 850 hPa temperatures and temperature anomalies valid from a) 0000 UTC 02 July, b) 0000 UTC 03 July, c) 0000 UTC 04 July, d) 0000 UTC 5 July, e) 0000 UTC 6 July, f) 0000 UTC 7 July, g) 0000 UTC 08 July, h) 0000 UTC 09 July, i) 0000 UTC 10 July 2010. Temperatures in °C and anomalies in standard deviations from normal.

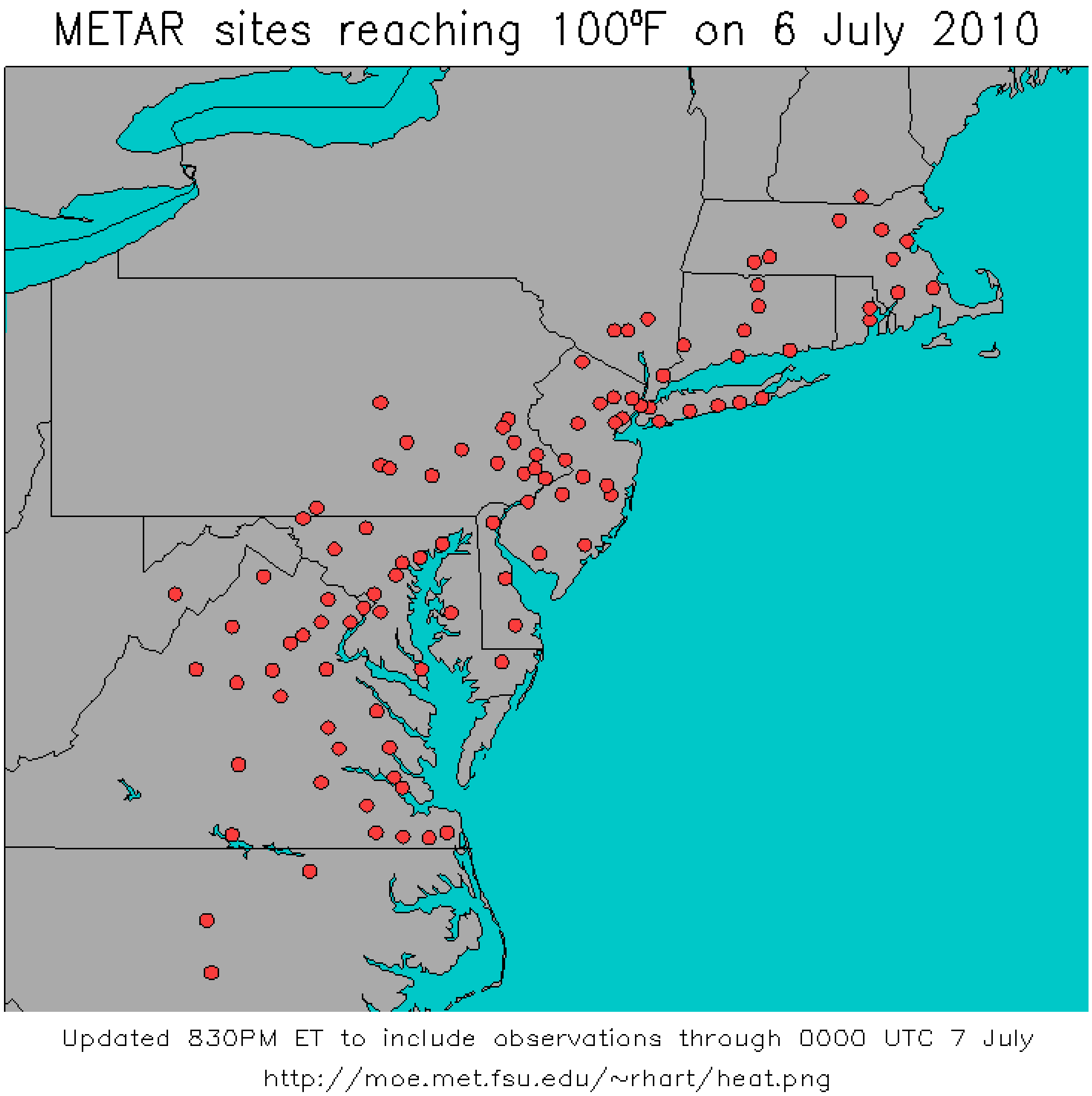

Figure 6. Locations in the eastern United States where high temperatures reached or exceeded 37.8 °C (100 °F). Map courtesy of Robert Hart the Florida State University.

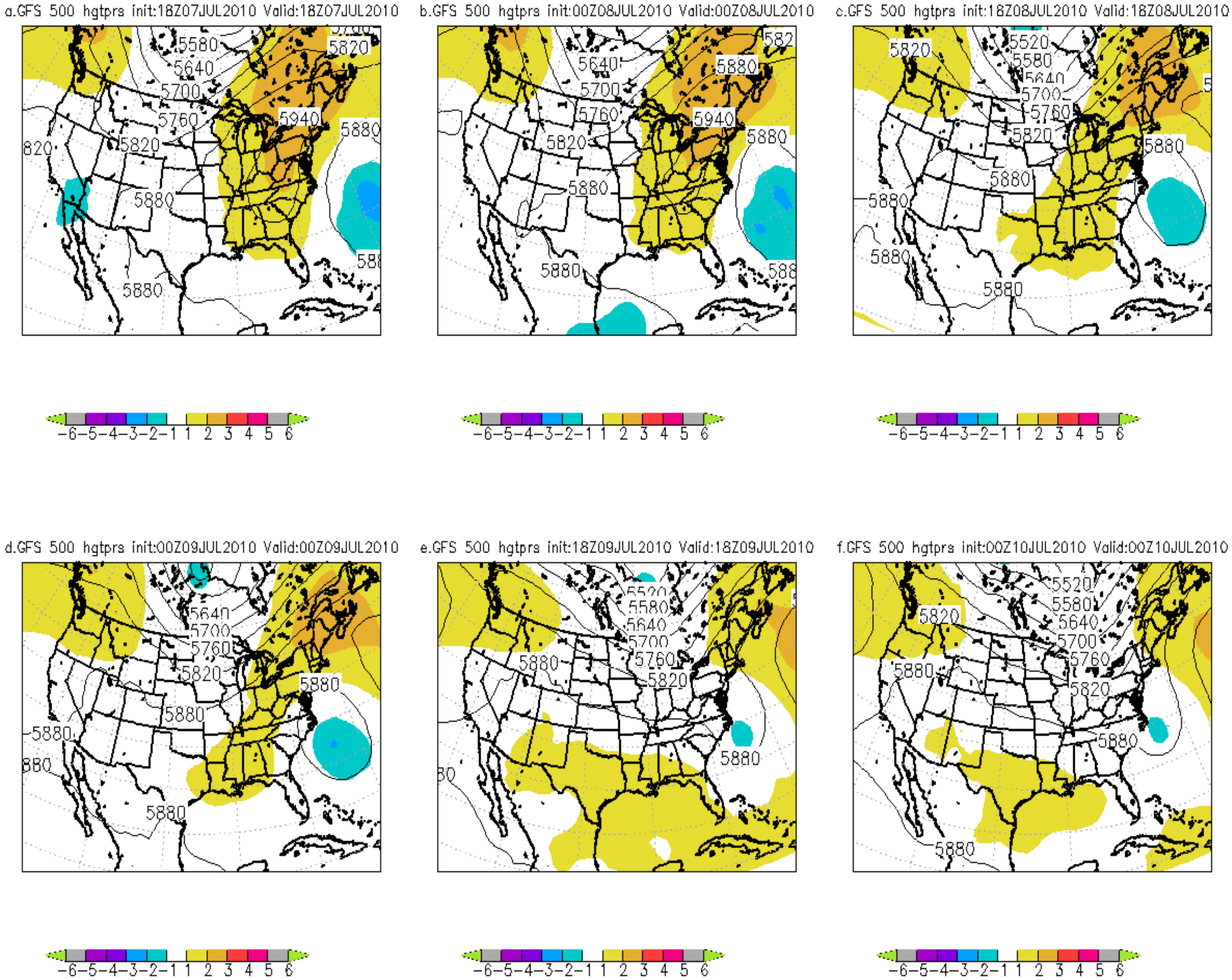

Figure 7. As in Figure 1 except for the period of a) 1800 UTC 07 July, b) 0000 UTC 08 July, c) 1800 UTC 08 July, d) 0000 UTC 09 July, e) 1800 UTC 09 July and f) 0000 UTC 10 July 2010.

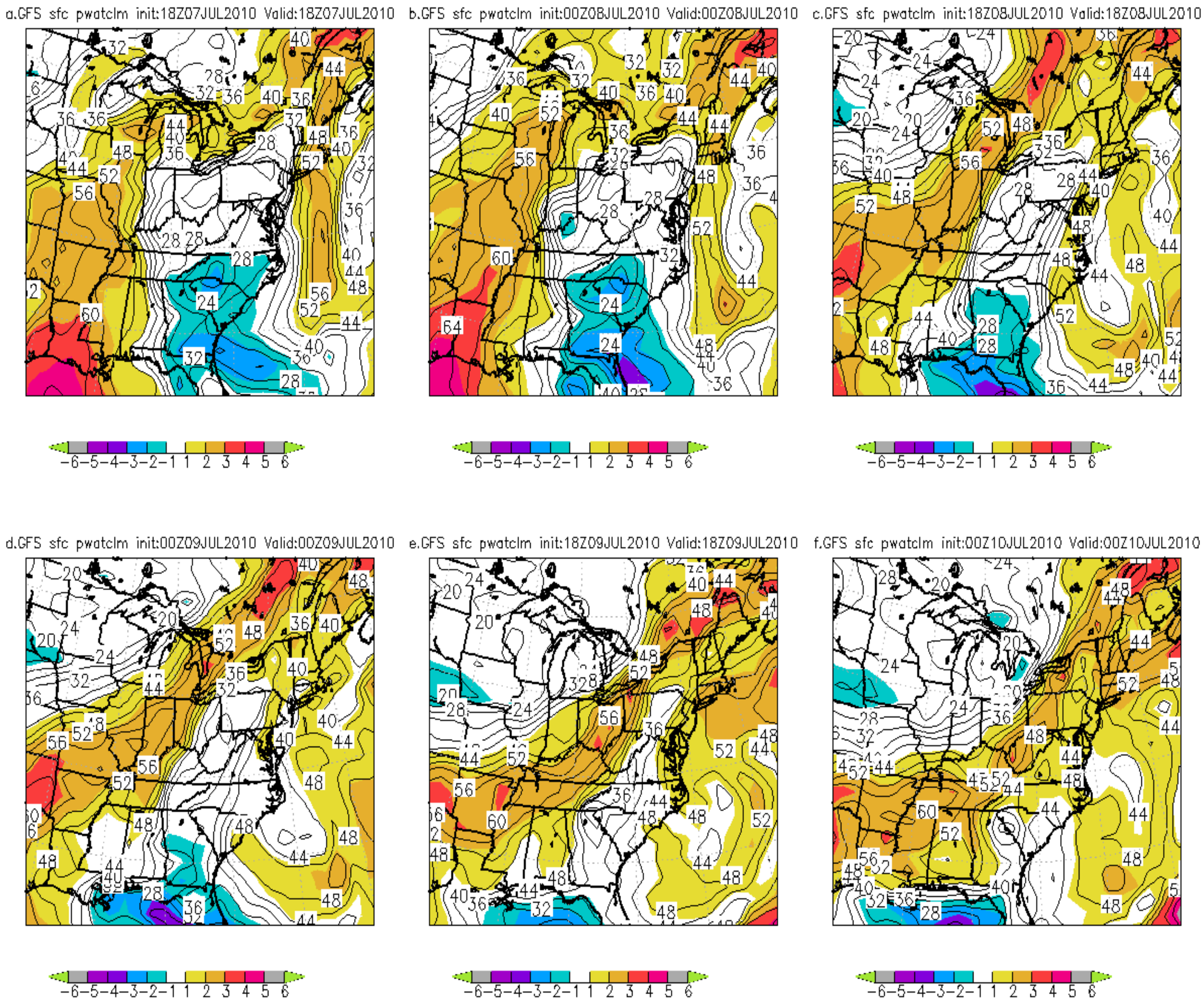

Figure 8. As in Figure 2 except for the period of a) 1800 UTC 07 July, b) 0000 UTC 08 July, c) 1800 UTC 08 July, d) 0000 UTC 09 July, e) 1800 UTC 09 July, and f) 0000 UTC 10 July 2010.

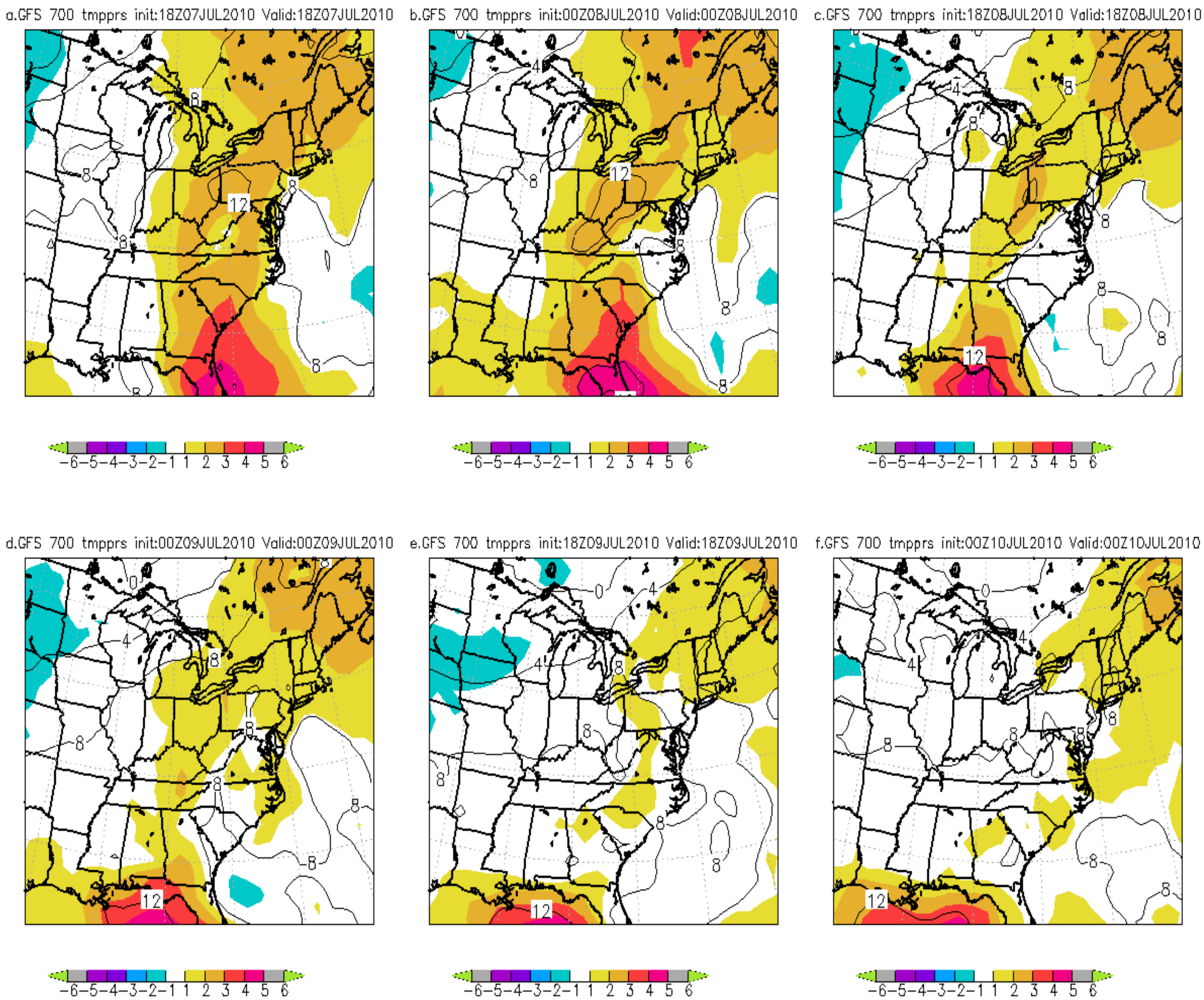

Figure 9. As in Figure 3 except for the period a) 1800 UTC 07 July, b) 0000 UTC 08 July, c) 1800 UTC 08 July, d) 0000 UTC 09 July, e) 1800 UTC 09 July, and f) 0000 UTC 10 July 2010.

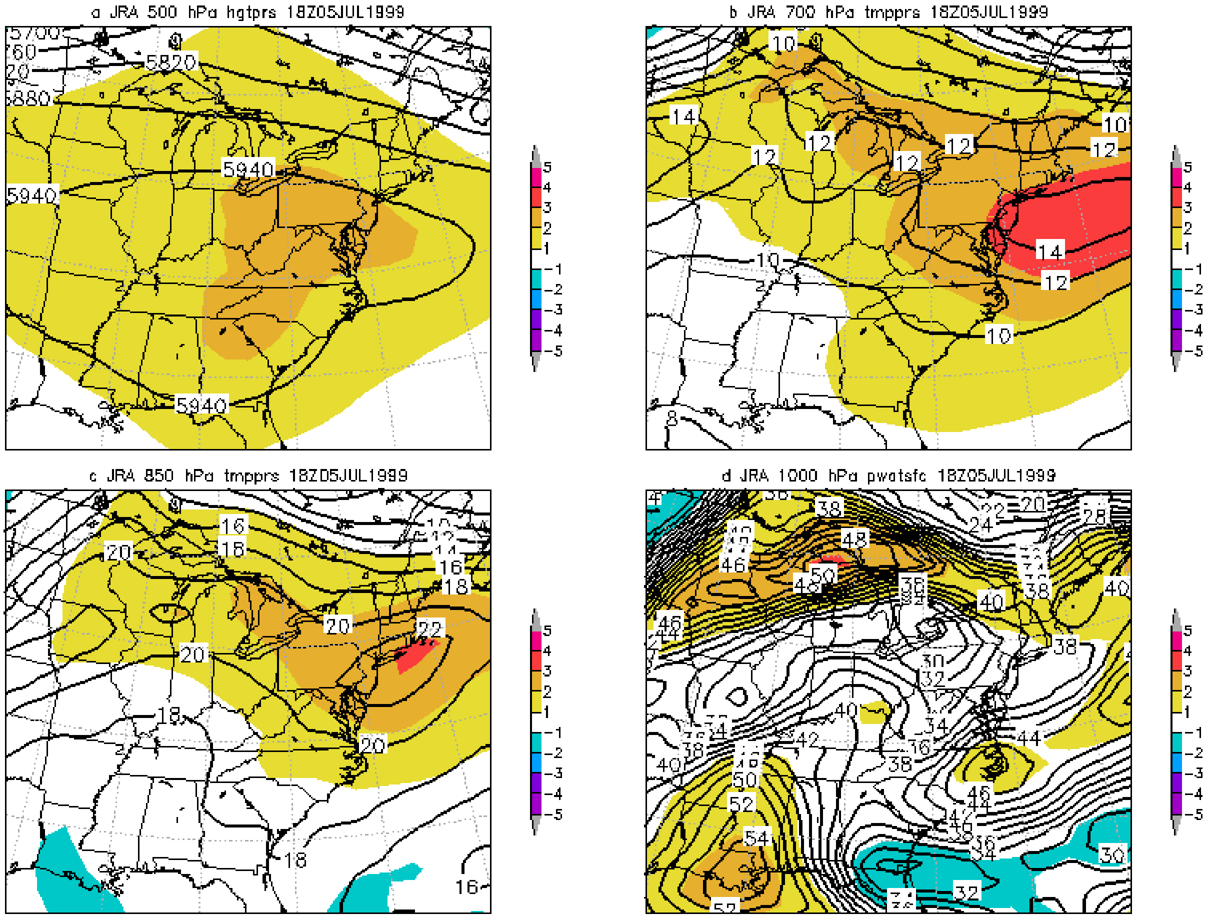

Figure 11. JRA data valid at 1800 UTC 05 July 1999 showing a) 500 hPa heights and height anomalies, b) 700 hPa temperatures and temperature anomalies, c) 850 hPa temperatures and temperature anomalies and d) precipitable water (mm) and precipitable water anomalies.

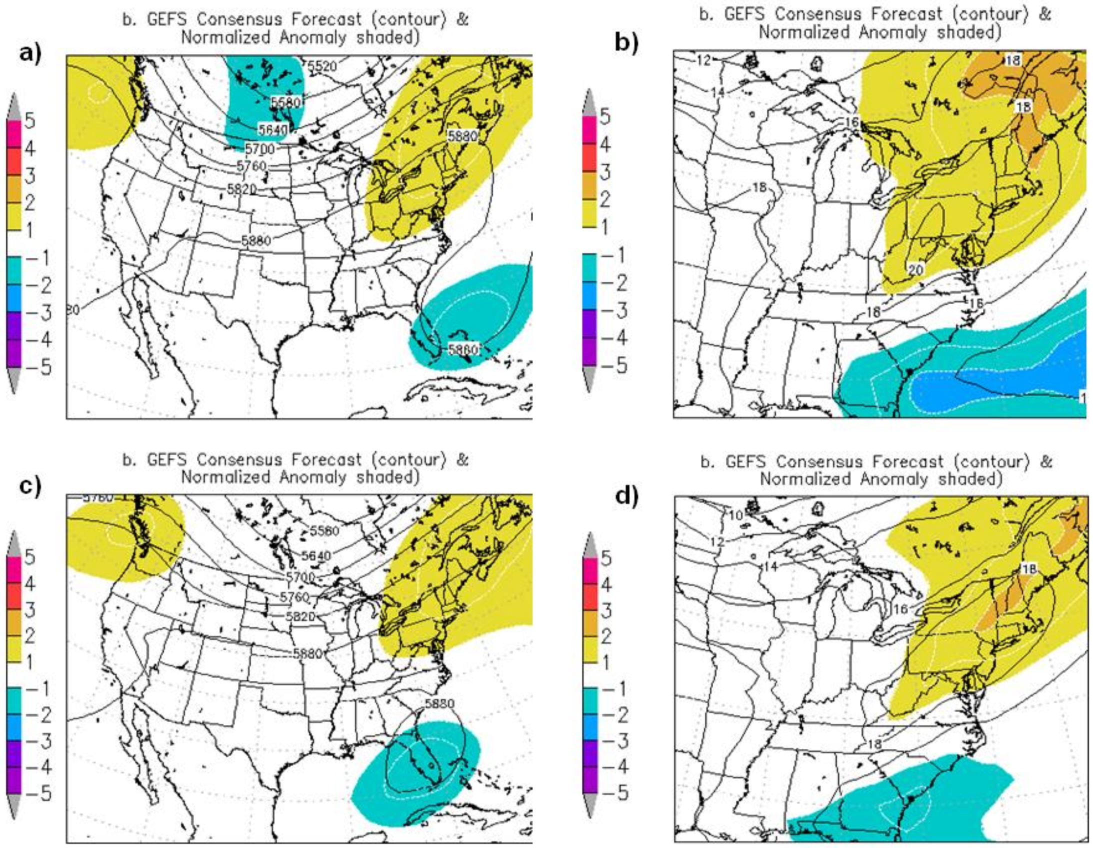

Figure 12. GEFS 126 hour and 150 hour forecasts of a) 500 hPa heights and height anomalies valid 1800 UTC 5 July, b) 850 hPa temperatures and temperature anomalies valid 1800 UTC 5 July, c) 500 hPa heights and height anomalies valid 1800 UTC 6 July, and d) 850 hPa temperatures and temperature anomalies valid 1800 UTC 6 July 2010.

Table 1. List of high temperatures at select sites by State for 4-7 July 2010. Values in red denote new records for the date. Underlined stations are National Climatic Data Center locations.

Maximum Temperatures

CITY	State	Sun	Mon	Tue	Wed	Thu
Caldwell	NJ	96	98	102	100	86
McGuire AFB	NJ	98	99	104	100	89
Millville	NJ	94	98	103	102	87
Mount Holly	NJ	97	99	104	102	87
Newark	NJ	101	102	103	101	87
Sussex Airport	NJ	95	96	101	98	89
Teterboro	NJ	97	99	103	101	86
Trenton	NJ	99	100	104	103	90
Wildwood	NJ	91	93	99	97	82
Albany	NY	89	94	96	95	93
Binghamton	NY	86	90	91	90	92
Islip	NY	97	95	101	96	85
New York, Central Park	NY	96	99	103	100	89
New York, JFK Airport	NY	101	97	101	100	87
New York, LaGuardia	NY	98	99	103	101	89
Poughkeepsie	NY	97	97	102	101	89
Rochester	NY	87	86	91	94	93
Syracuse	NY	88	94	94	93	94
White Plains	NY	95	96	102	97	86
Allentown	PA	96	98	101	99	93
Altoona	PA	90	93	94	94	94
Doylestown	PA	96	100	101	102	86
Harrisburg	PA	94	97	100	99	97
Lancaster	PA	95	97	101	99	94
Philadelphia	PA	96	98	102	103	90
Pittsburgh	PA	88	91	93	93	92
Pottstown	PA	98	100	103	102	93
Reading	PA	97	100	102	101	95
Selinsgrove	PA	97	102	103	102	104
University Park	PA	90	93	93	92	94
Williamsport	PA	94	97	98	99	99

Maximum Temperatures

CITY	State	Sun	Mon	Tue	Wed	Thu
Charlottesville-Albemarle	VA	96	99	100	101	98
Dulles Intl. Airport	VA	95	96	102	101	95
Fort Belvoir	VA	95	98	102	101	95
Manassas	VA	95	99	100	102	95
Norfolk	VA	92	98	98	98	86
Richmond	VA	96	100	103	104	96
Roanoke	VA	94	96	98	100	100
Charleston, Yeager Airport	WV	91	95	97	97	97
Morgantown	WV	89	93	94	93	92
Parkersburg	WV	91	92	95	95	93
Annapolis	MD	87	91	95	97	87
Baltimore, Inner Harbor	MD	97	101	105	102	94
BWI Airport	MD	96	100	105	101	94
Hagerstown	MD	98	100	100	100	97
Ocean City	MD	88	91	100	93	83
Reagan National Airport	DC	94	99	100	102	95
Dover AFB	DE	95	96	102	101	84
Georgetown	DE	92	97	102	97	86
Wilmington	DE	94	97	103	103	87
Bridgeport	CT	97	93	98	95	84
Hartford	CT	95	98	102	99	89
New Haven	CT	94	95	100	98	86
Willimantic	CT	93	96	99	95	87
Windsor Locks	CT	94	97	102	100	92
Newport	RI	90	92	98	87	81
Providence	RI	94	97	102	92	86
Smithfield	RI	90	93	97	91	84
Barre-Montipelier	VT	85	90	91	92	90
Burlington	VT	88	92	95	95	96
Springfield	VT	90	95	96	96	90
Concord	NH	91	97	99	97	92
Manchester	NH	90	99	99	95	92
Nashua	NH	93	99	101	98	92
Portsmouth, Pease AFB	NH	93	91	98	86	84
Keene	NH	88	93	97	93	90
Rochester	NH	90	95	98	91	87

Maximum Temperatures

CITY	State	Sun	Mon	Tue	Wed	Thu
Boston, Logan Intl.	MA	95	89	100	83	88
Chatham	MA	92	90	94	89	80
Chicopee Falls, Westover AFB	MA	92	98	101	99	92
Hyannis	MA	92	88	95	89	81
Lawrence	MA	94	97	99	94	90
Martha's Vineyard	MA	90	91	95	90	82
Orange	MA	89	96	99	98	89
Westfield	MA	94	98	103	100	91
Worcester	MA	87	92	96	93	86
Augusta	ME	88	91	94	88	82
Bangor	ME	89	91	91	89	83
Portland	ME	89	89	95	85	79
Sanford	ME	91	93	99	90	88
Caribou	ME	85	80	86	93	88

Table 2. As in Table 1 except sorted on the days where the high was 100 °F or greater on 6 July 2010 when 45 sites reached or exceeded 100 °F.

City	State	Sun	Mon	Tue	Wed	Thu	Fri
Baltimore, Inner Harbor	MD	97	101	105	102	94	93
BWI Airport	MD	96	100	105	101	94	93
McGuire AFB	NJ	98	99	104	100	89	90
Mount Holly	NJ	97	99	104	102	87	92
Trenton	NJ	99	100	104	103	90	91
Millville	NJ	94	98	103	102	87	89
Newark	NJ	101	102	103	101	87	87
Teterboro	NJ	97	99	103	101	86	89
New York, Central Park	NY	96	99	103	100	89	90
New York, LaGuardia	NY	98	99	103	101	89	90
Pottstown	PA	98	100	103	102	93	95
Selinsgrove	PA	97	102	103	102	104	95
Richmond	VA	96	100	103	104	96	93
Wilmington	DE	94	97	103	103	87	89
Westfield	MA	94	98	103	100	91	91
Atlantic City	NJ	96	99	102	98	87	88
Caldwell	NJ	96	98	102	100	86	88
Poughkeepsie	NY	97	97	102	101	89	91
White Plains	NY	95	96	102	97	86	88
Philadelphia	PA	96	98	102	103	90	91
Reading	PA	97	100	102	101	95	94
Dulles Intl. Airport	VA	95	96	102	101	95	91
Fort Belvoir	VA	95	98	102	101	95	93
Dover AFB	DE	95	96	102	101	84	87
Georgetown	DE	92	97	102	97	86	89
Hartford	CT	95	98	102	99	89	89
Windsor Locks	CT	94	97	102	100	92	91
Providence	RI	94	97	102	92	86	86
Bedford	MA	94	98	102	95	93	93
Sussex Airport	NJ	95	96	101	98	89	89
Islip	NY	97	95	101	96	85	85
New York, JFK Airport	NY	101	97	101	100	87	87
Allentown	PA	96	98	101	99	93	91
Doylestown	PA	96	100	101	102	86	88
Lancaster	PA	95	97	101	99	94	90
Nashua	NH	93	99	101	98	92	93
Chicopee Falls, Westover AFB	MA	92	98	101	99	92	92
Harrisburg	PA	94	97	100	99	97	91
Charlottesville-Albemarle	VA	96	99	100	101	98	92
Manassas	VA	95	99	100	102	95	91

Hagerstown	MD	98	100	100	100	97	92
Ocean City	MD	88	91	100	93	83	84
Reagan National Airport	DC	94	99	100	102	95	93
New Haven	CT	94	95	100	98	86	89
Boston, Logan Intl.	MA	95	89	100	83	88	91

Table 3. Summary of stations in Table 1 meeting or exceeding 100, 95 and 90F.

Threshold	4^{th}	5^{th}	6^{th}	7^{th}	8th
100 or greater	2	10	45	30	2
95 or greater	33	54	71	57	14
90 or greater	66	78	82	75	41