The extreme rainfall event of 17-18 July 1942

By
Richard H. Grumm, Charles Ross, and Elissa Smith
National Weather Service State College, PA

1. Overview

A "*phenomenally heavy*" rain event (US Weather Bureau 1942) affected north-central Pennsylvania and adjacent New York on 17-18 July 1942. Particularly hard hit counties included Elk, Cameron, McKean, and Potter counties in Pennsylvania based on bucket and jar surveys of the rainfall. The Weather Bureau publication claimed that his event far exceeded all known record events. The isohyetal map 24 hour rainfall showed several areas with over 20 inches and one area with a 35 inch contour. The rainfall axis extended from northwest to southeast, a classic modern Mesoscale convective system rainfall pattern in northwest flow about a large subtropical ridge.

The Pittsburgh Post-Gazette newspaper (appendix) reported that western Pennsylvania was in the midst of a three-day heat wave that saw temperatures rise to 96 degrees on July 17, 1942. The low temperature that morning was 77 degrees. Additional reporting through July 19, 1942 indicates the city's public pools and rivers were jammed with residents seeking relief from the heat. Numerous deaths were also reported due to heat related issues.

The rainfall analysis was literally based on a bucket survey with Short Run, PA having 11.9+ inches in a crock, 11.3+ in a wooden bucket, and 8.2+ inches in a milk pail. Pans, tubs, buckets, paint cans, coffee pots and similar devices rounded out the instrumentation set. Emporium, PA had 25.6 inches in a crock and Coudersport, PA had 25.5 inches of rainfall in a Milk Can. Official NWS COOP data analysis of this event indicates no 24 hour records and the official gage Coudersport recorded 8.48 inches. Far less than the Milk Can.

The gage at Smethport "*reported 6.68 inches before the gage was lost*" (Gelber, 2002). Smethport reportedly set the 24 hour rainfall record of 30.60 inches on 17 July with an event total rainfall estimated to be 34.50 inches. There were no official rain gages within 40% of these values and as noted the Smethport gage was lost before the event ended. The official gage data indicated that when combining 17-18 July data rainfall, amounts over 8.48 inches were recorded and values much over 10 inches were difficult to find. Clearly, there was a large discrepancy between rain gage and bucket analysis. Gelber (2002) argues that the official 24 hour rainfall record for Pennsylvania is 19.81 inches set in Park Place, PA in July 1947.

The impacts of the heavy rain were significant (Gelber, 2002) and similar to those one might associated with an intense widespread 6-10 inch rainfall event. The flooding claimed 16 lives, 6 of which occurred in Port Allegany. McKean County had damage to our lost 16 bridges.

The 20 July 1942 edition of the Pittsburgh Post-Gazette reported on flash flooding that occurred over north central Pennsylvania from this event. The article outlined reports of several feet of water in the Canastea Paper Company plant in Johnsonburg, Elk County. Additionally, there were reports of only slight damage in St. Marys, PA to the St. Joseph's convent. An earthen dam in Austin, PA failed and resulted in widespread damage to train cars and houses. The reports in the Post-Gazette did not indicate any extraordinary impacts from an historic 30 inch rainfall event.

This was a historically significant and interesting event. An analysis was conducted to examine the conditions under which this "record event" occurred under. The 20th Century re-analysis data was used to re-create the pattern which produced the rainfall. The NWS COOP data was used to verify the findings that suggest this event was a rather typical MCS or ring-of-fire pattern over a a subtropical ridge which typically proceeds a heat wave or warm episode.

2. Methods and Data

The 20th Century re-analysis data was used to reconstruct the large scale pattern during the time of the record flood event.. These data were displayed using GrADS with an emphasis on the antecedent conditions, the pattern evolution and the features often associated with heavy rainfall events.

The National Centers for Environmental Information (NCEI) daily data were used to examine the rainfall with COOP sites and to examine temperature records. It will be shown as the ridge built over the eastern United States, an extensive heat wave affected much of the southeastern United States.

3. The Pattern

The 500 hPa heights and anomalies show the evolution of the large scale pattern from 0000 UTC 13 to 21 July 1942 (Fig. 1). These data show a large subtropical ridge over the eastern United States at 0000 UTC 13 July with 500 hPa with a closed 5940 m contour[1]. A deep trough dragged lower heights and cooler air into the northeast 15-16 July before the ridge began to build back into the region. By 0000 UTC 18 July 1942 there was a closed 6000 m contour of the Ohio Valley. The massive subtropical ridge slowly retrograded to the west over the next 3 days (Figs. 1f-i).

During the period focused near the rainfall event, the pattern over the eastern United States is shown in 6-hour increments from 0000 UTC 17-19 July 1942. Initially, the retreating cold air over New England was present (Fig. 2a) and a nose of warm air was evident to the west. The warm air built into the east and 850 hPa temperatures soared to over 24C from the Great Lakes to the southeastern United States (Fig. 2c-i).

[1] The appearance of 6000 m and 5940 m contours in the 20th Century data verse modern data implies a bias and imperfect analysis.

The precipitable water (PW: Fig. 3) data showed the retreating dry air over New England with earlier cool surge and much above normal PW air to the northwest coming over the ridge. The axis of high PW air moved into western Pennsylvania and New York from 1800 UTC through about 1200 UTC 18 July 1942. PW values were well over 50 mm at times with PW anomalies in the +2 to +3σ range (Fig. 3c-e). This was an ideal ring-of-fire or MCS pattern as shown.

The flow over around the ridge produced a strong 850 hPa jet. The peak wind anomalies with this jet were detectable in the 850 hPa u-wind components indicating strong west-northwesterly flow (Fig. 4). These data imply a strong west-northwesterly 850 hPa jet moved across western Pennsylvania between 1800 UTC 17 July to 1800 UTC 18 July 1942 (Fig. 4d-h). The 850 hPa v-wind anomalies (Fig. 5) show the northerly wind anomalies peaking around 1200 UTC 18 July 1942.

The surface pressure pattern indicated a ridge off the East Coast (Fig. 5) with lower pressure to the west. As the rain event unfolded, the surface ridge moved across the southeastern United States and an implied frontal trough moved over Pennsylvania and New York. This trough showed signs of a weak low off the coast of New Jersey by 1800 UTC 18 July 1942 which then moved to the east (Fig. 5h-i). The deep trough and implied low suggest there was a strong wave associated with the flow over the ridge which produced the rainfall.

The 250 hPa flow over the eastern United States showed above normal northwesterly flow (Fig 6).

The pattern evolution implied a developing subtropical ridge and heat wave with a heavy rainfall event on the periphery of the building ridge. The next section examines the concept of the developing subtropical ridge and heat wave.

4. Temperature records and the heat wave

The number of maximum temperature and maximum overnight minimum temperature records set or tied during July 1942 are shown in Figures 7 & 8 respectively. These data indicated a prolonged period of record setting warmth from 18 to 23 July 1942. The surge of record high minimum temperatures is quite telling (Fig. 8). Of the 964 record high overnight low temperatures, 397 of them were set on 18 July 1942.

Tables 1 & 2 show the daily NCEI data for the month. Like the images, the period of 16 to 21 July stood out as an period of time when the overnight lows remained near record levels. This implied that the moisture content, as shown by the PW anomalies, was abnormally high for a long time which likely limited overnight radiative cooling.

The areas affected by the heat from 17 to19 July 1942 is shown in Figure 9. The upper panel shows all the record high temperatures set or tied and the lower panel shows the areas affected by the record high overnight low temperatures. The high temperature records extended from the

Upper Midwest across the Mid-Atlantic region into the southeastern United States. The heavy rainfall area over Pennsylvania as on the northern edge of the record heat.

The area affected by the record high overnight lows covered a similar but far more expansive area. The warm overnight temperatures appear to feedback to the broad area of above normal PW which came over the large subtropical ridge. The record warm overnight low temperatures are shown in Figure 10. These data show extensive the deep warm moist air was and how on the morning of 18 July 1942 it was extremely warm over most of the eastern United States.

The Post-Gazette in Pittsburgh carried articles relative to the heat wave from 18-21 July 1942 including an end to the heat wave (appendix).

5. Summary

A "*phenomenally heavy*" event (US Weather Bureau 1942) affected north-central Pennsylvania and adjacent New York on 17-18 July 1942. An examination of COOP and available weather station data at the time would reveal little useful information about this event. Two day rainfall amounts over 8.48 inches in the station data are not readily available. However, the extensive bucket, milk can, paint can, and coffee can survey conducted in 1942 lead the Weather Bureau to acknowledge this event as an extreme rainfall event. It is somewhat subjective as to whether or not this was truly a record event. However, the pattern in which the rainfall event occurred was recognized as a pattern favoring heavy rainfall and using modern datasets and concepts this event clearly occurred in a pattern which favored an extreme mesoscale rainfall event.

The rainfall pattern shown in the Weather Bureau publication is a familiar pattern of rainfall often associated with an MCS in northwesterly flow. Additionally, convective rainfall events and MCSs often occur as the subtropical ridge builds over a region during a significant heat wave or warm episode. The 20th Century re-analysis data clearly show that this rainfall event fell on the periphery of a massive subtropical ridge (Fig. 1) and the NCEI temperature data show that during and after the event there was a extensive period of record warmth over much of the eastern United States (Fig. 9,10,11, and 12). The extensive number of record high overnight minimums attests to the extent of the event and the likely deep moisture which limited overnight cooling during the event.

The 500 hPa pattern showed the strong subtropical ridge. It is believed that the appearance of 6000 m and 5940 m contours in the 20th Century data during this event may reflect a bias verse modern datasets. This **bias may reflect an imperfect analysis based on how these data were derived.** Experiences using these data for the 1930s heat waves and the hurricane of 1938 appear to reveal some bias toward higher 500 hPa heights and extreme PW values. Despite these potential biases, these data do provide a signal that likely reflects the overall pattern. The images produced here were compared to the images produced in the 1942 publication and they are quite similar. Despite some minor bias toward higher heights, it is clearly that a strong subtropical ridge brought a heat wave to the eastern United States 17-21 July 1942.

The surge of high PW air (Fig. 3) over the ridge was an ideal ring-of-fire or MCS pattern as shown. Along with the strong LLJ at 850 hPa which implied strong west-northwesterly flow, the surge of high PW was an ideal pattern for a high end mesoscale convective rainfall event. The high PW air likely contributed to the extensive area of above normal overnight low temperatures on 18 July 1942. The deep warm air moist air provided the moisture for the rainfall and the moisture which likely limited overnight radiative cooling.

The deep trough in the surface pattern along the East Coast suggested that there was a strong wave associated with the flow over the ridge which produced the rainfall. This may fit the model of a a ridge-roller which often accompanies the development of MCSs along the periphery of the subtropical ridge (Galarneau and Bosart 2006; Galarneau and Bosart 2006).

The re-analysis and climate data all reinforce that there was likely an ideal environment for an extreme convective heavy rainfall event. The pattern, where the rain fell in this pattern, and the known sequence of events associated with subtropical ridges suggest many key ingredients for a record rainfall event were in place. But was the bucket survey scientifically accurate? Modern datasets only use official gages and measuring devices so the validity of this record to some is somewhat subjective. Thus, it would be interesting to initialize a high resolution model to determine if a 3km convective allowing model could replicate anything close to the estimated 30 inches of rainfall in its QPFs.

6. A**cknowledgements**

Aaron Tyburski of replication of historic images from the delicate report and proof reading.

7. References

Galarneau, TJ,Jr. and LF Bosart: 2006: Ridge Roller: Mesoscale disturbances on the periphery of cutoff anticyclones. Preprint, Symp. on Challenges of Severe Convective storms, Atlanta, GA, American Meteor Soc., P1.11.

Galarneau, T. J., Jr., L. F. Bosart, and A. R. Aiyyer, 2008: Closed anticyclones of the subtropics and midlatitudes: A 54-yr climatology (1950–2003) and three case studies. Synoptic–Dynamic Meteorology and Weather Analysis and Forecasting: A Tribute to Fred Sanders, Meteor. Monogr., No. 55, Amer. Meteor. Soc., 349–392.

Gelber, Ben, 2002: The Pennsylvania Weather Book. Rutgers University Press.268pp.

Weather Bureau: 1944: Daily and Hourly Precipitation Supplement Storm of 17-18 July, 1942. New York-Pennsylvania. US Department of Commerce Weather Bureau in cooperation with War Departement Corps of Engineers. Hydrologic Unit, Albany, NY.

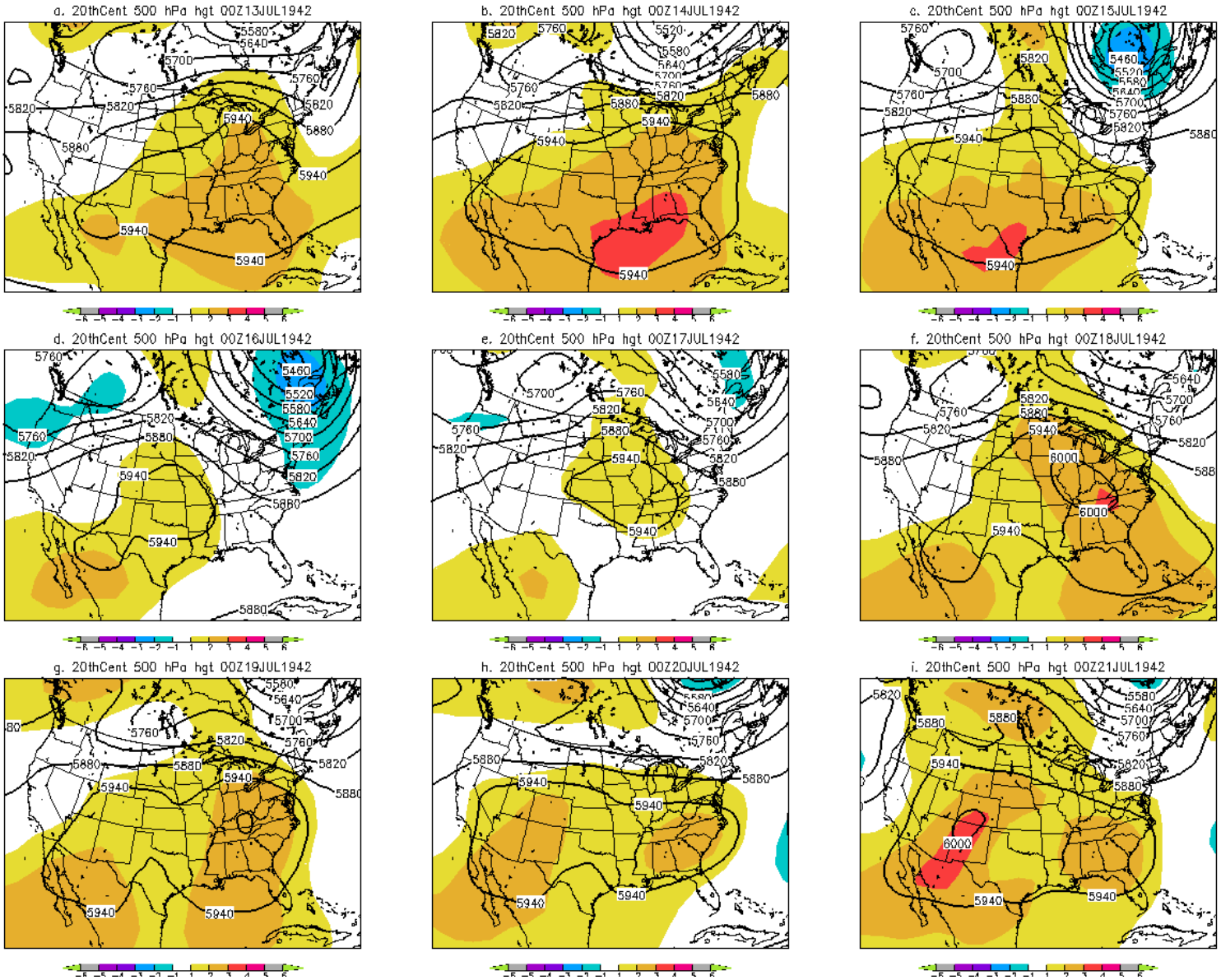


Figure 1. The Twentieth Century Reanalysis data showing 500 hPa heights (m) and the 500 hPa height anomalies as departures from normal from the 1980-2010 CFS climatology. Data are Every 24 hours from a) 0000 UTC 13 July through i) 0000 UTC 21 July 1942. **Return to text.**

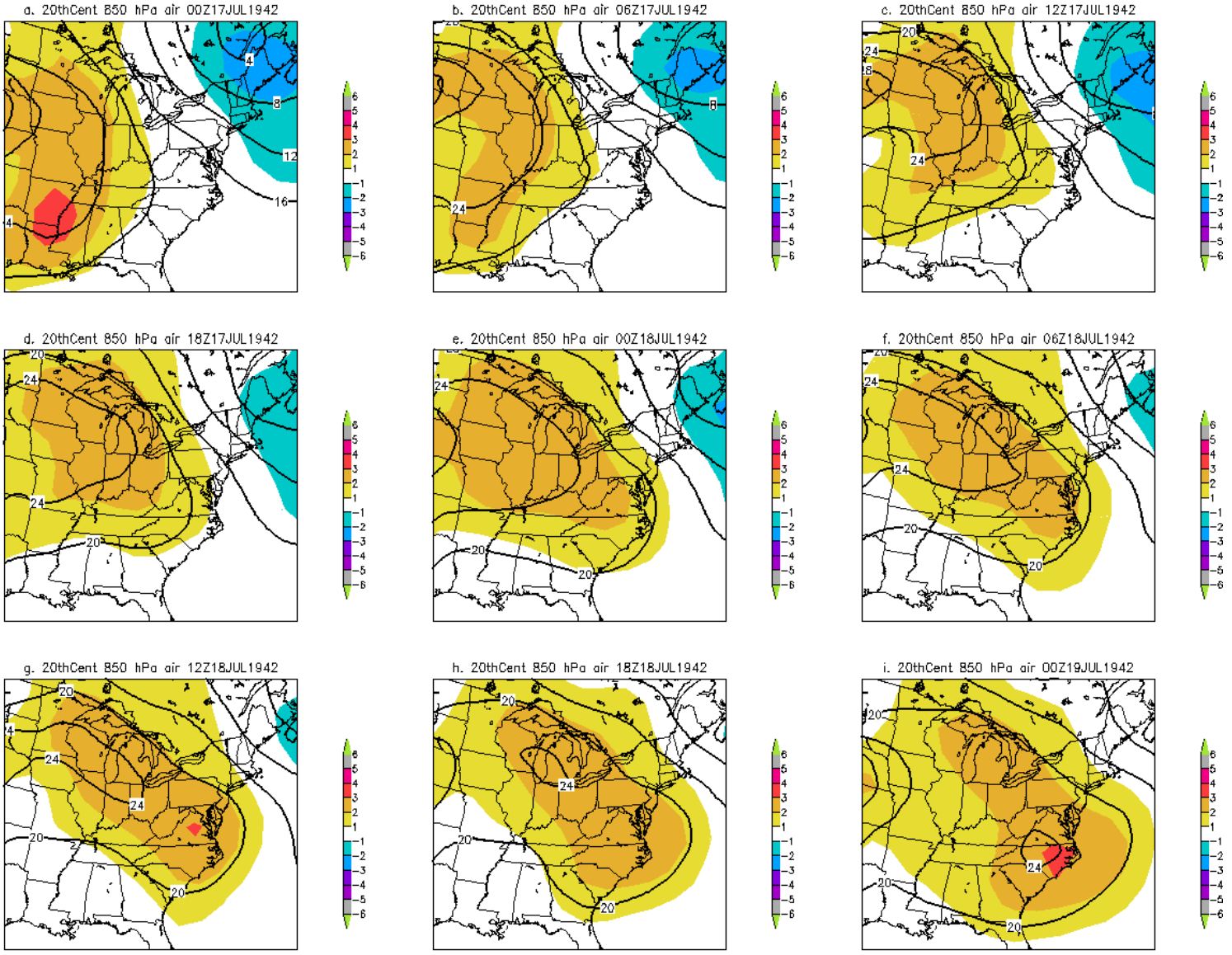


Figure 2. As in Figure 1 except for 850 hPa temperatures and temperature anomalies Data are every 6 hours from a) 0000 UTC 17 July through i) 0000 UTC 19 July 1942. **Return to text.**

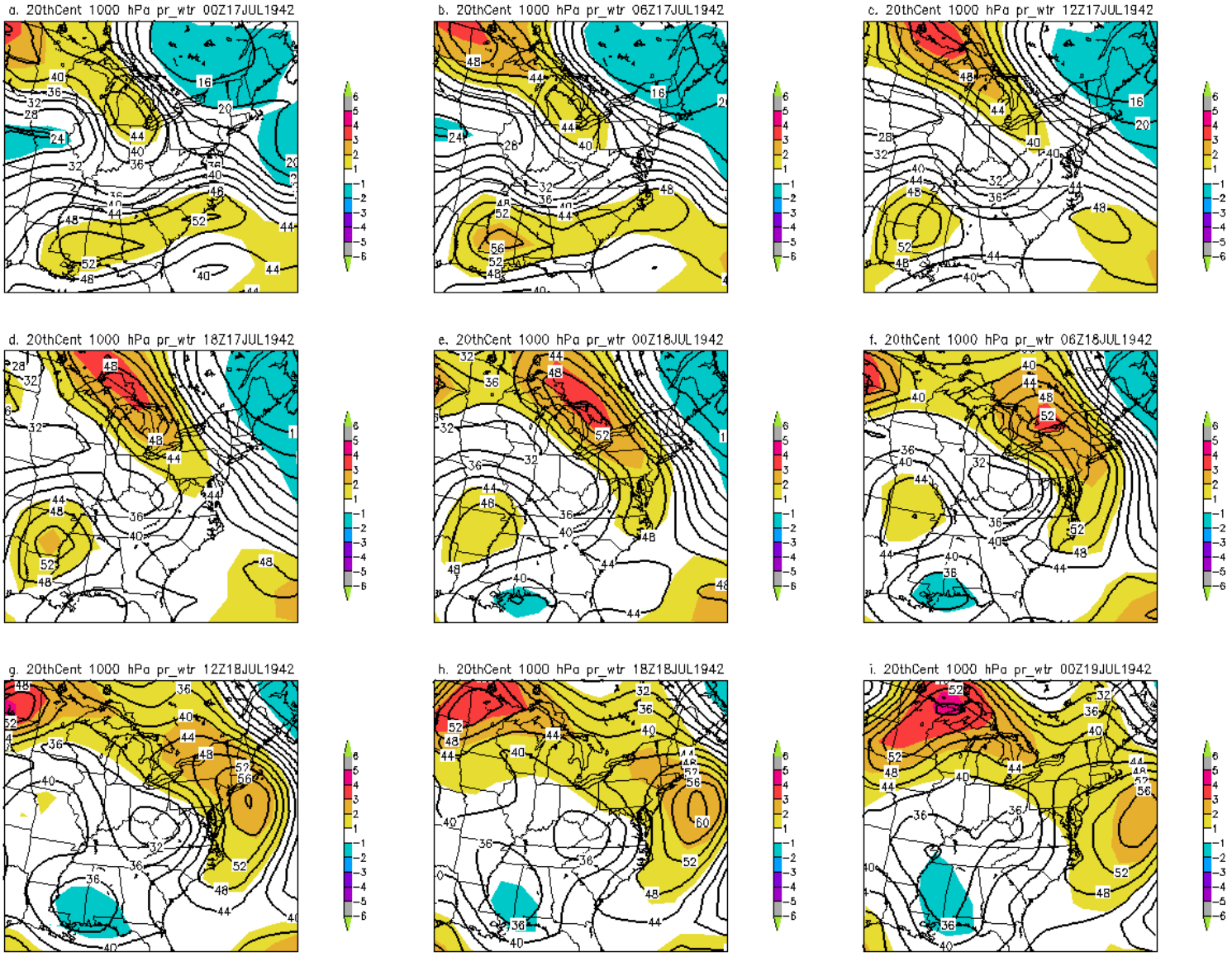


Figure 3. As in Figure 2 except for precipitable water. **Return to text.**

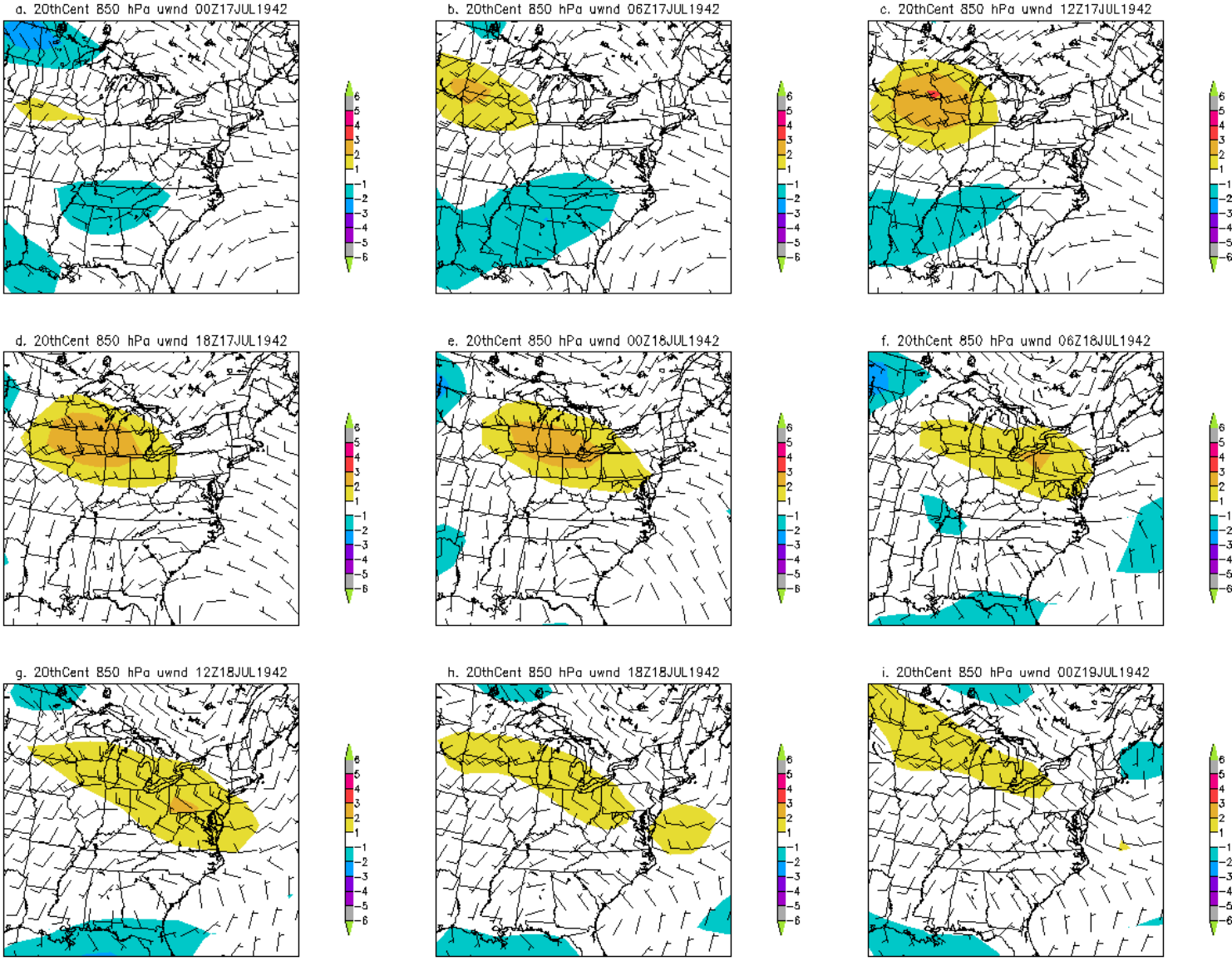


Figure 4. Data as in Figure 2 except for 850 hPa winds and u-wind anomalies. **Return to text.**

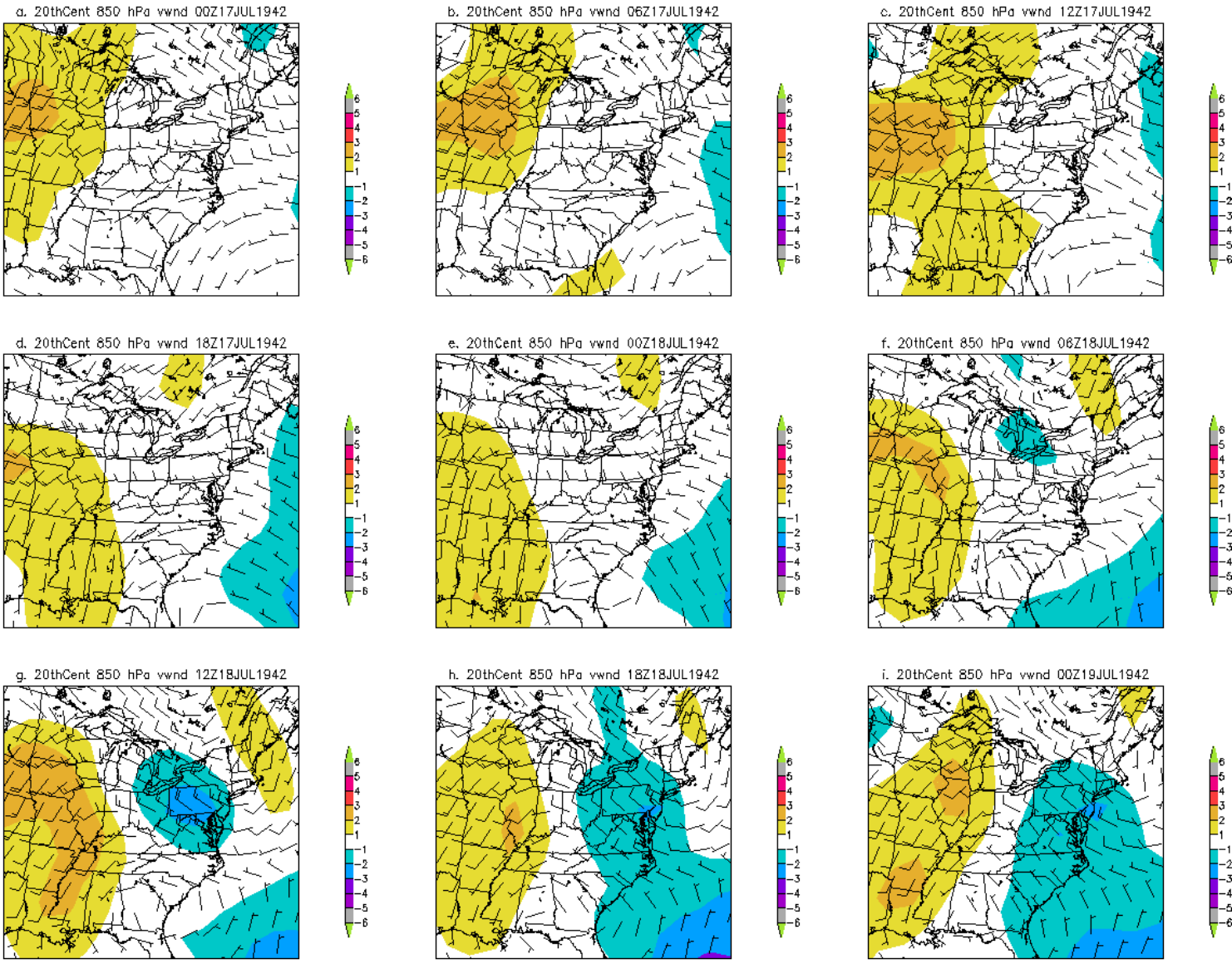


Figure 5. As in Figure 4 except for 850 hPa v-wind anomalies. **Return to text.**

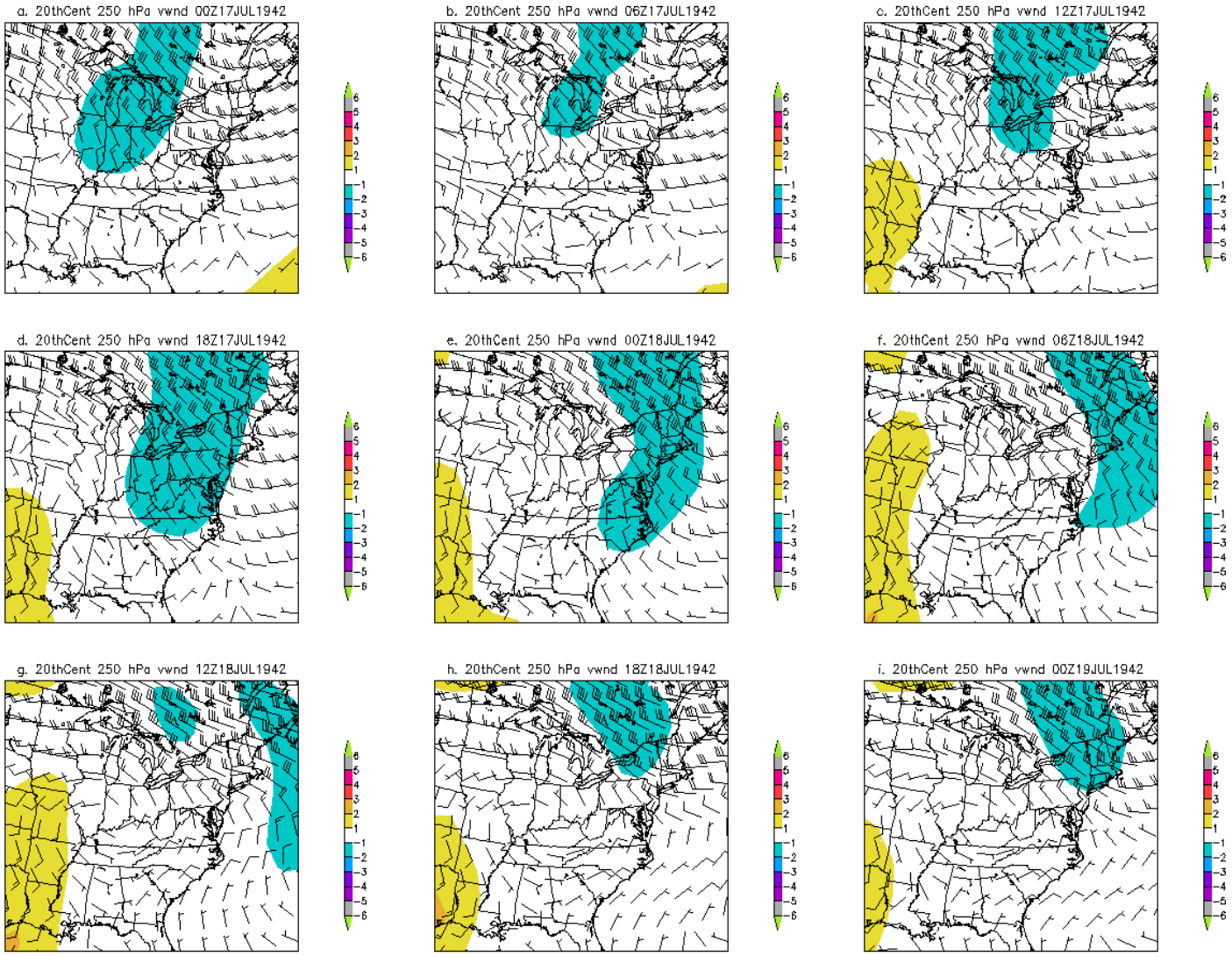
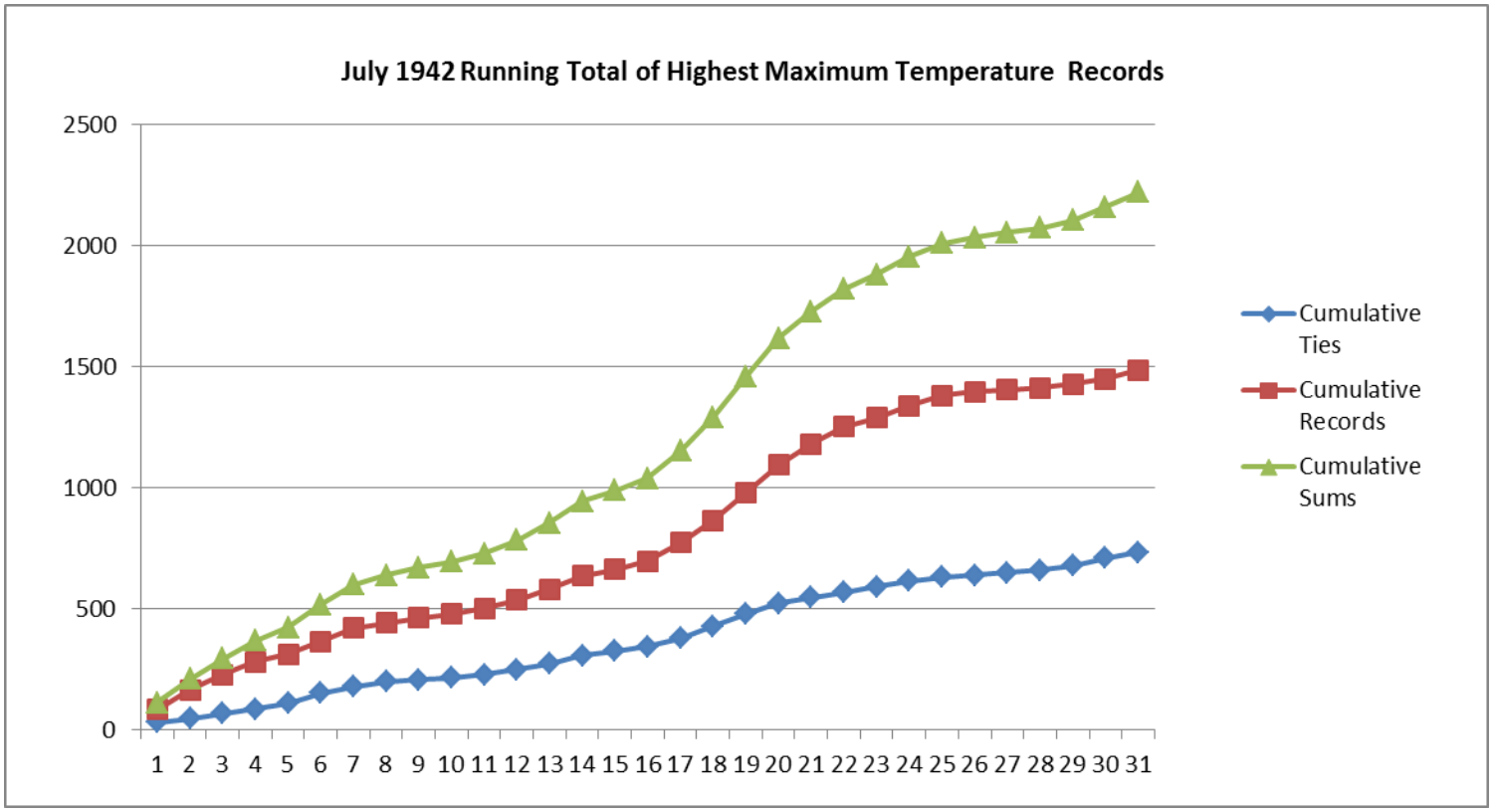


Figure 6. As in Figure 5 except for 250 hPa wind anomalies. **Return to text.**



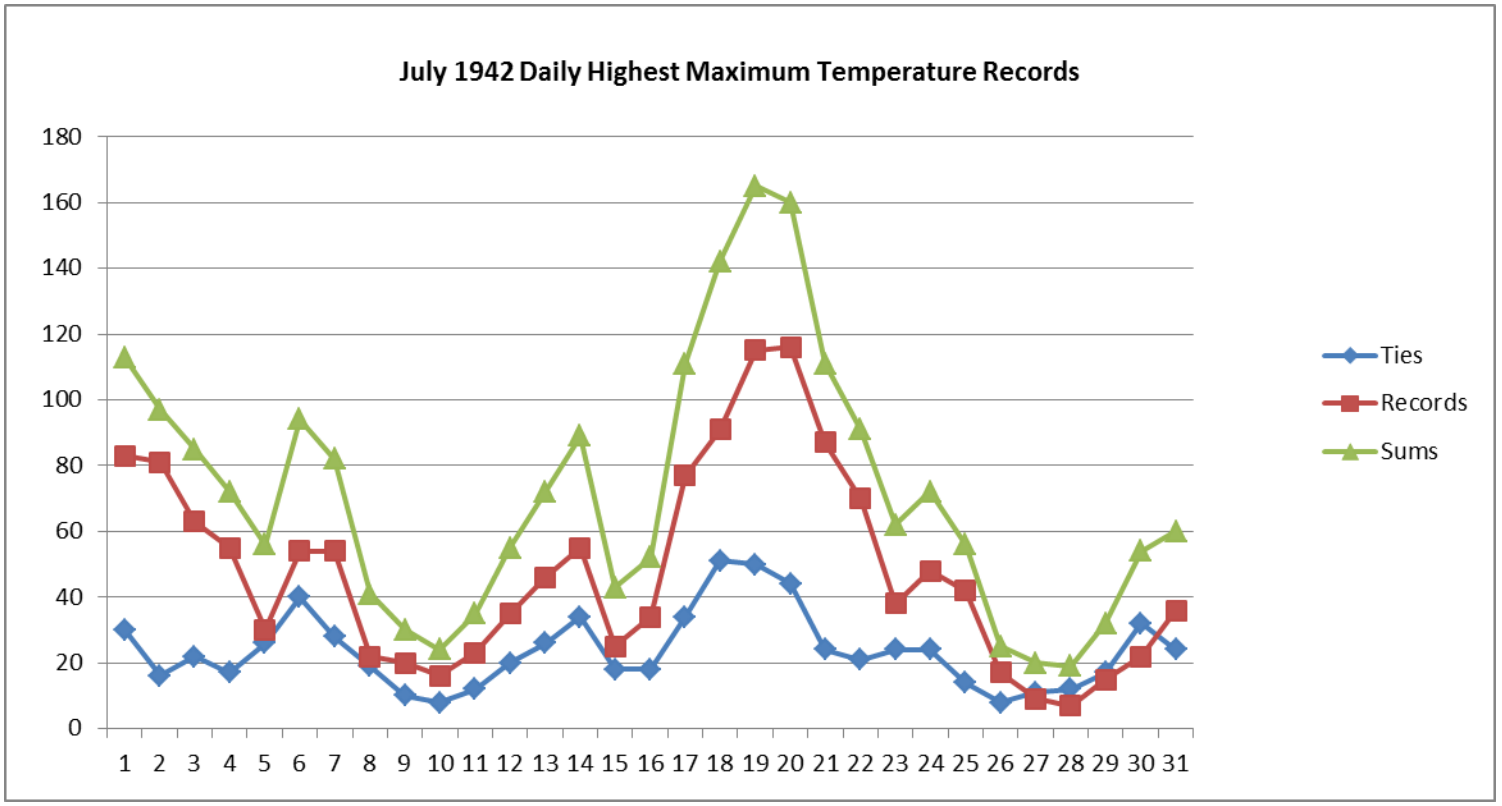
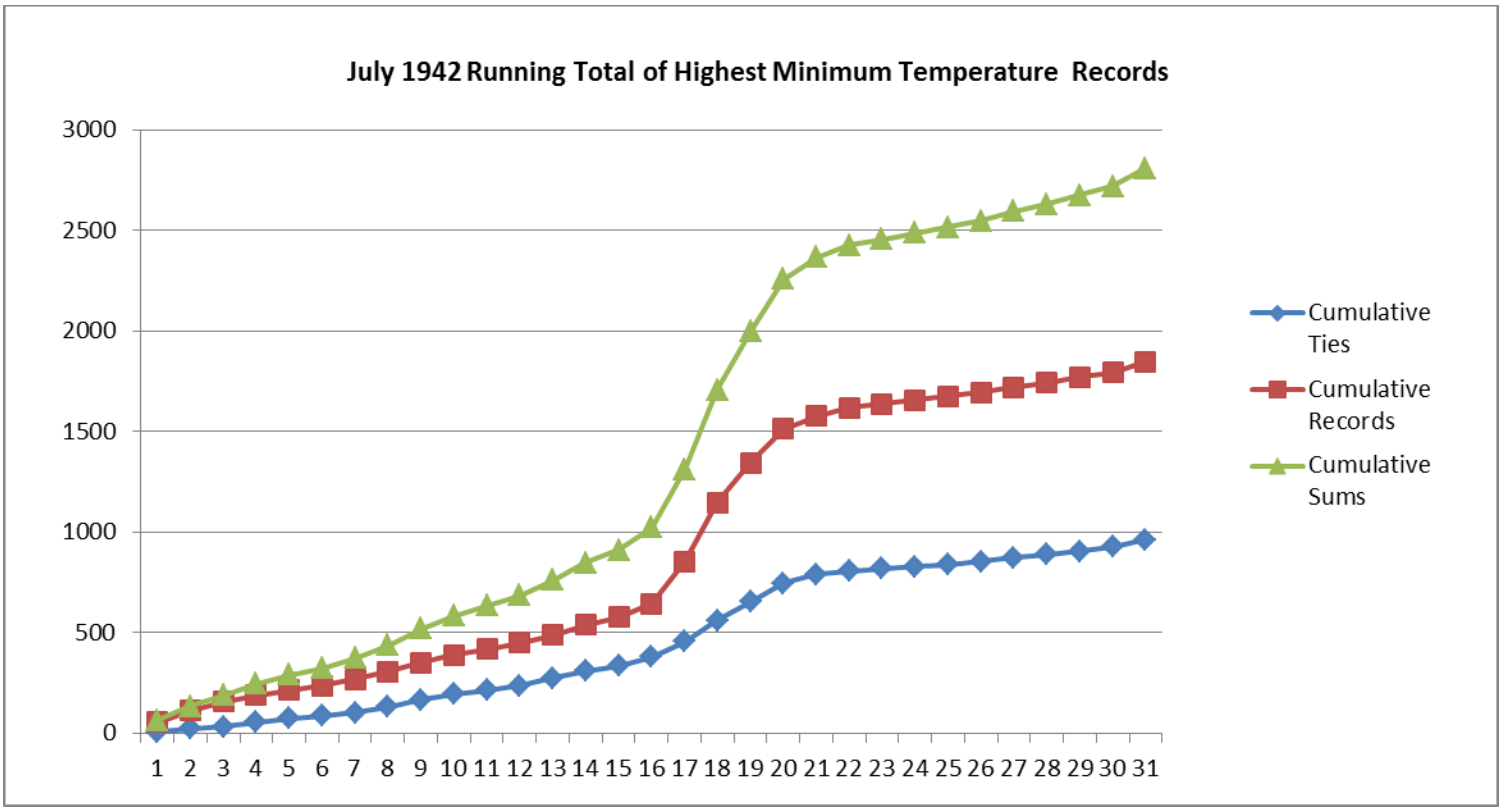


Figure 7. NCEI data showing the record high temperatures set, tied, and the sum of both. The upper panel shows the accumulation of the records for the month and the low panel shows the number of records set each day. **Return to text.**



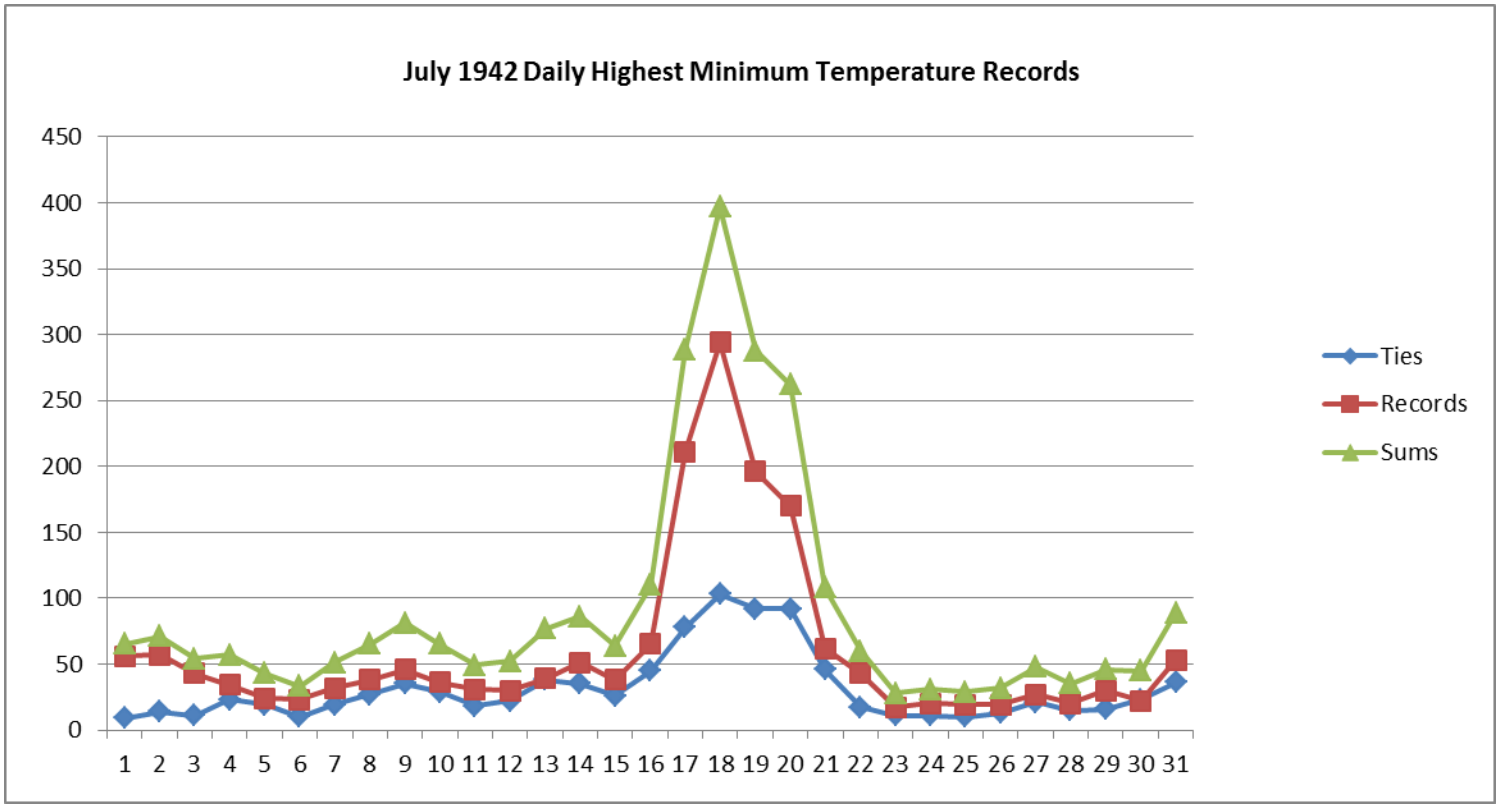
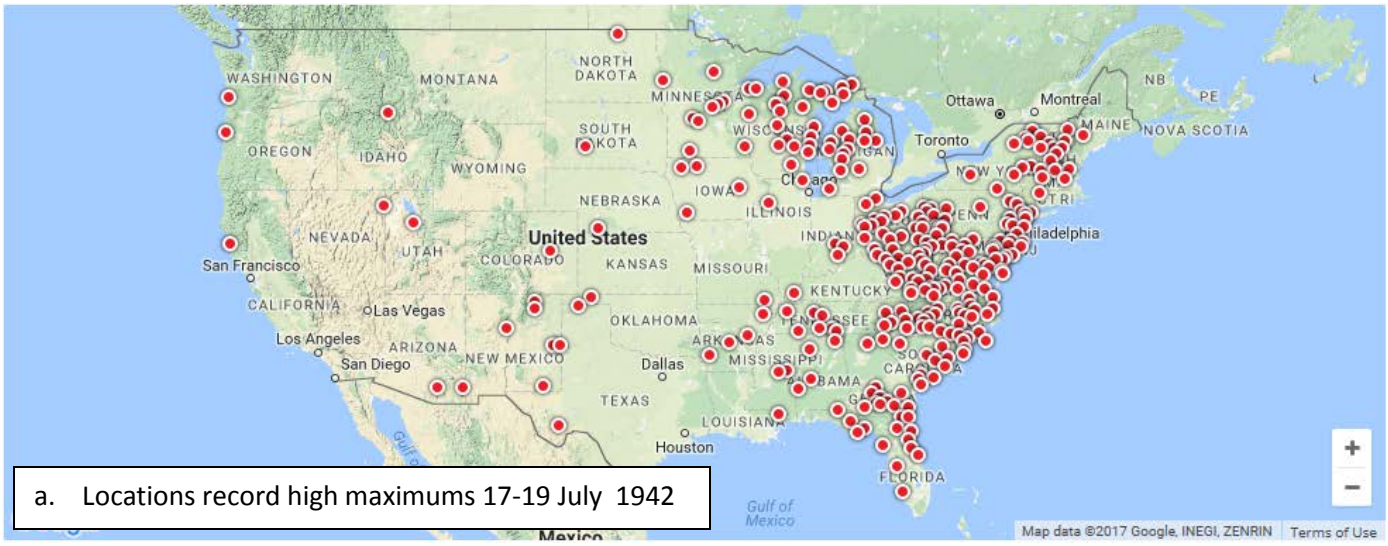
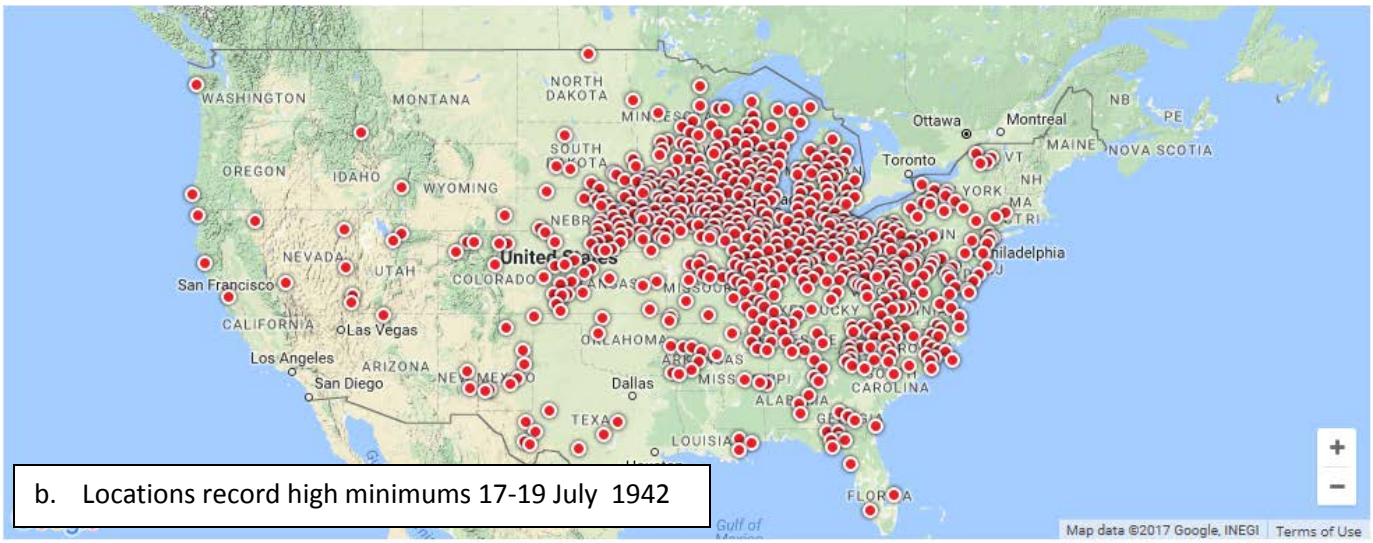


Figure 8. As in Figure 7 except for record high overnight low temperatures. Return to text.

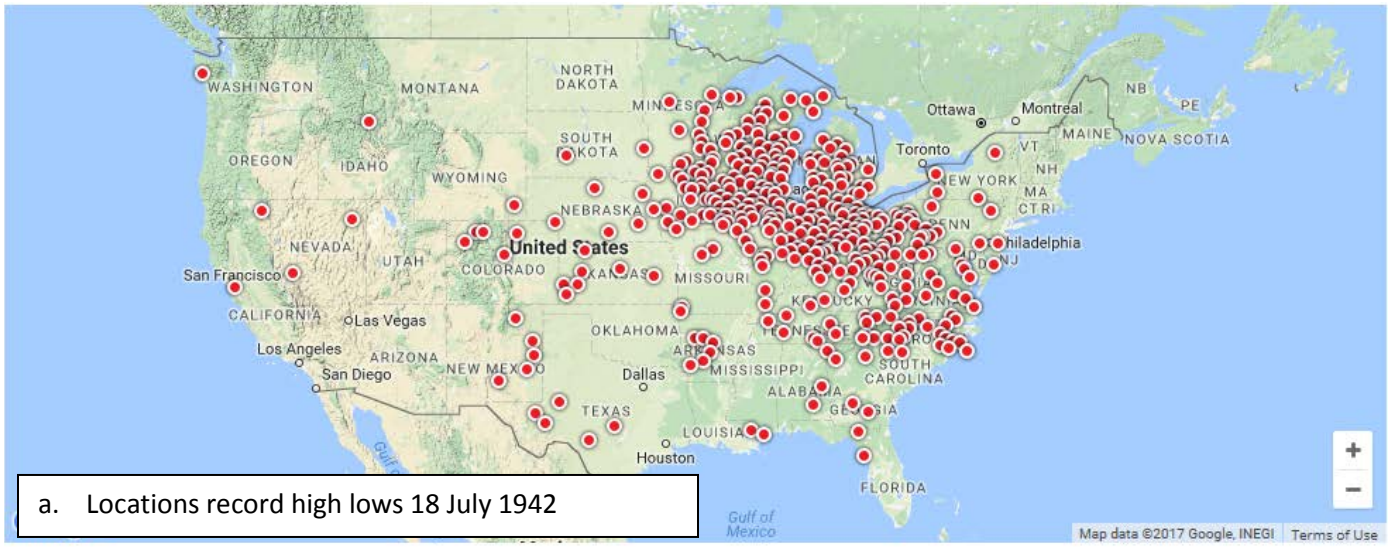


a. Locations record high maximums 17-19 July 1942

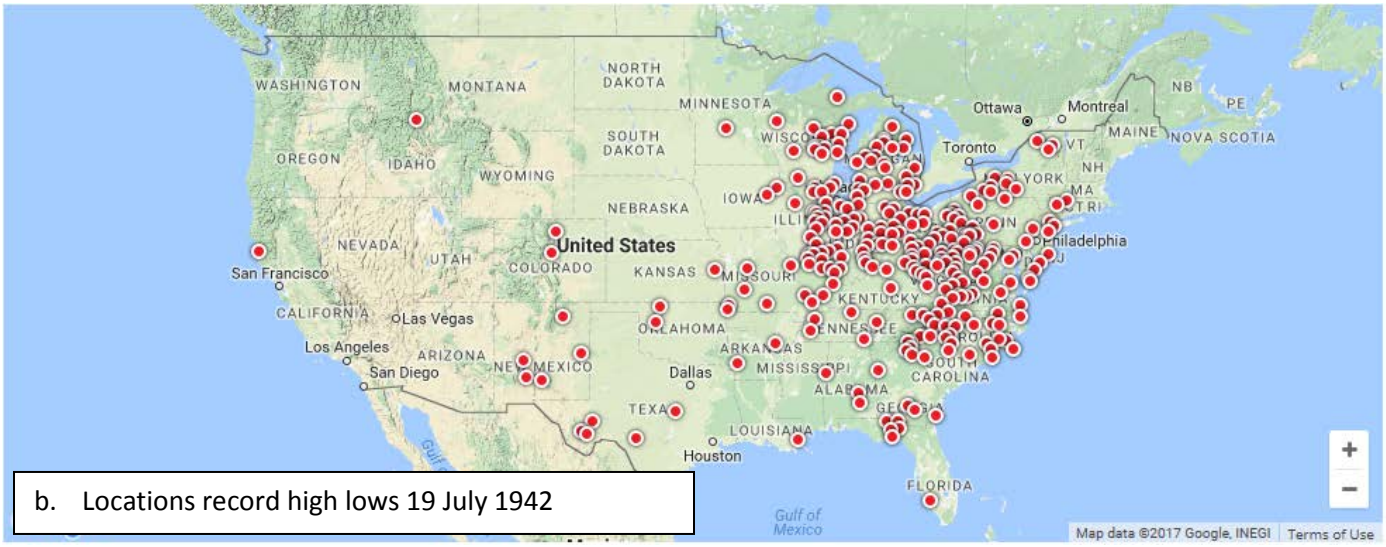


b. Locations record high minimums 17-19 July 1942

Figure 9. NCEI plots of the number of record set or tied for high temperatures (upper) and record high minimum temperatures for the period of 17 to 19 July 1942. **Return to text.**



a. Locations record high lows 18 July 1942



b. Locations record high lows 19 July 1942

Figure 10. As in Figure 9 except for the daily locations of the record high overnight lows for 18 and 19 July 1942. **Return to text.**

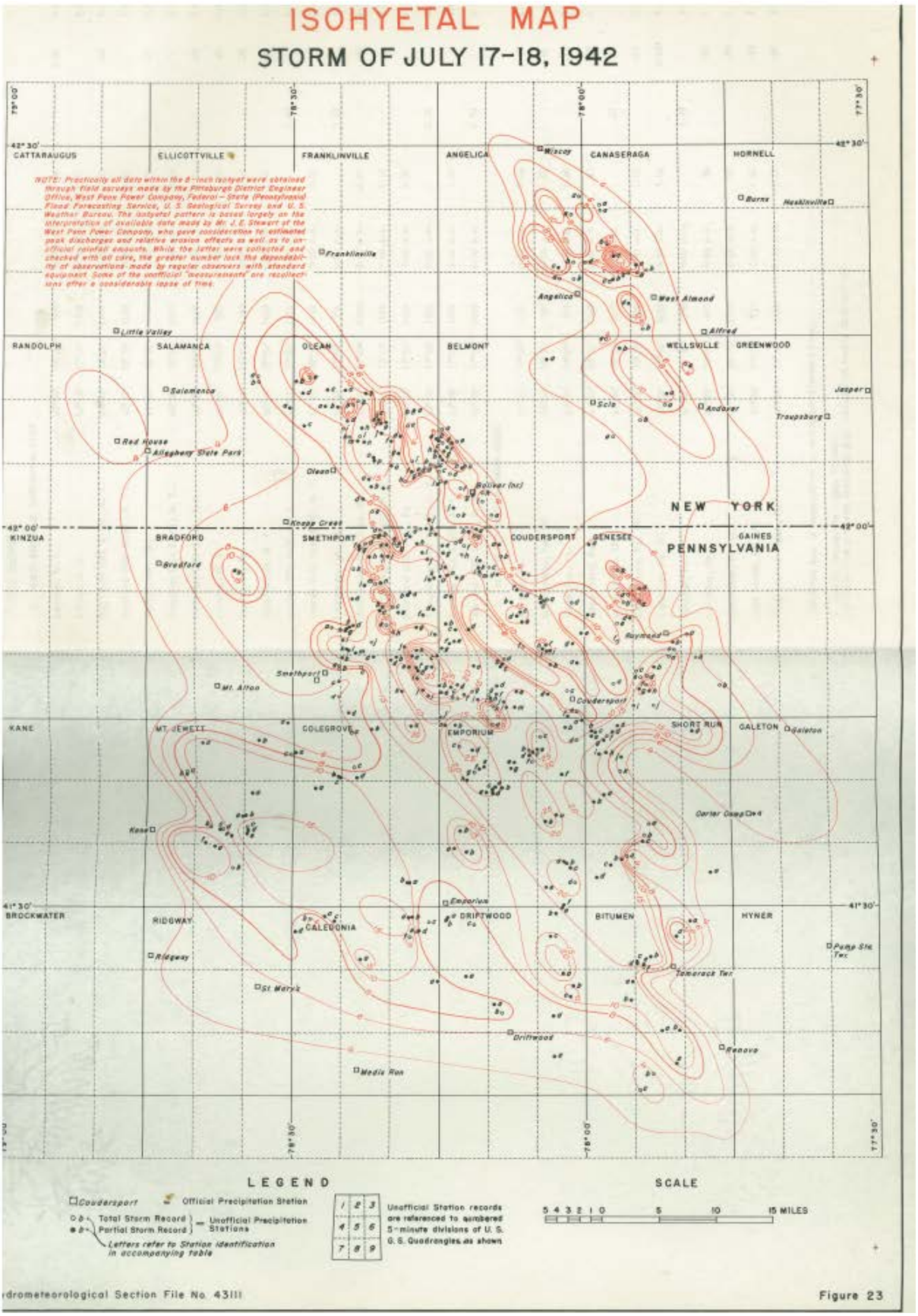


Figure 11. US Weather Bureau bucket survey analysis of rainfall. Reproduced from the Supplement of the Storm of July 17-18 1942 Daily hourly precipitation report. **Return to text.**

Date	Ties	Records	Sums	Cumulative Ties	Cumulative Records	Cumulative Sums
7/1/1942	9	56	65	9	56	65
7/2/1942	14	57	71	23	113	136
7/3/1942	11	43	54	34	156	190
7/4/1942	23	34	57	57	190	247
7/5/1942	19	24	43	76	214	290
7/6/1942	10	23	33	86	237	323
7/7/1942	19	32	51	105	269	374
7/8/1942	27	38	65	132	307	439
7/9/1942	35	46	81	167	353	520
7/10/1942	29	36	65	196	389	585
7/11/1942	18	31	49	214	420	634
7/12/1942	22	30	52	236	450	686
7/13/1942	38	39	77	274	489	763
7/14/1942	35	51	86	309	540	849
7/15/1942	26	38	64	335	578	913
7/16/1942	45	65	110	380	643	1023
7/17/1942	78	211	289	458	854	1312
7/18/1942	103	294	397	561	1148	1709
7/19/1942	92	196	288	653	1344	1997
7/20/1942	92	170	262	745	1514	2259
7/21/1942	46	62	108	791	1576	2367
7/22/1942	17	43	60	808	1619	2427
7/23/1942	11	17	28	819	1636	2455
7/24/1942	11	20	31	830	1656	2486
7/25/1942	10	19	29	840	1675	2515
7/26/1942	13	19	32	853	1694	2547
7/27/1942	21	27	48	874	1721	2595
7/28/1942	15	20	35	889	1741	2630
7/29/1942	16	30	46	905	1771	2676
7/30/1942	23	22	45	928	1793	2721
7/31/1942	36	53	89	964	1846	2810
Sums	**964**	**1846**	**2810**	**14551**	**28992**	**43543**

Table 1. List of daily record high minimum temperature records. Data include the date, records tied, records broken, and a summation of all record tied or broken. Monthly accumulated statistics for each record type are included. Return to text.

Date	Ties	Records	Sums	Cumulative Ties	Cumulative Records	Cumulative Sums
7/1/1942	30	83	113	30	83	113
7/2/1942	16	81	97	46	164	210
7/3/1942	22	63	85	68	227	295
7/4/1942	17	55	72	85	282	367
7/5/1942	26	30	56	111	312	423
7/6/1942	40	54	94	151	366	517
7/7/1942	28	54	82	179	420	599
7/8/1942	19	22	41	198	442	640
7/9/1942	10	20	30	208	462	670
7/10/1942	8	16	24	216	478	694
7/11/1942	12	23	35	228	501	729
7/12/1942	20	35	55	248	536	784
7/13/1942	26	46	72	274	582	856
7/14/1942	34	55	89	308	637	945
7/15/1942	18	25	43	326	662	988
7/16/1942	18	34	52	344	696	1040
7/17/1942	34	77	111	378	773	1151
7/18/1942	51	91	142	429	864	1293
7/19/1942	50	115	165	479	979	1458
7/20/1942	44	116	160	523	1095	1618
7/21/1942	24	87	111	547	1182	1729
7/22/1942	21	70	91	568	1252	1820
7/23/1942	24	38	62	592	1290	1882
7/24/1942	24	48	72	616	1338	1954
7/25/1942	14	42	56	630	1380	2010
7/26/1942	8	17	25	638	1397	2035
7/27/1942	11	9	20	649	1406	2055
7/28/1942	12	7	19	661	1413	2074
7/29/1942	17	15	32	678	1428	2106
7/30/1942	32	22	54	710	1450	2160
7/31/1942	24	36	60	734	1486	2220

Table 2. As in Table 1 except for the number of daily record high maximum temperatures. Return to text.

Appendix of Post-Gazette data from google searches.

SIX REPORTED KILLED AS TWO DAMS BURST

Northwestern Pennsylvania Communities Inundated By Flood Waters

Many Northwestern Pennsylvania communities were inundated late yesterday by flood waters after the bursting of two dams.

Reservoirs at Austin, near Coudersport on the upper Allegheny River, and above Johnsonburg, on the Clarion River, were reported to have given way.

The Johnsonburg flood apparently was the most serious. Water from the Ketner Dam isolated the community. Reports from nearby communities said that three persons had been drowned and that most of the 4000 residents had taken to the hills.

Chlorine Tanks Explode

Chlorine tanks at a paper mill exploded, and the gas added to the peril, Red Cross units were being sent from Punxsutawney.

At Ridgeway, below Johnsonsburg, one-third of the community was reported flooded. C. Paul Paddock, Elk County Civilian Defense Chairman, placed al his personnel on the double alert.

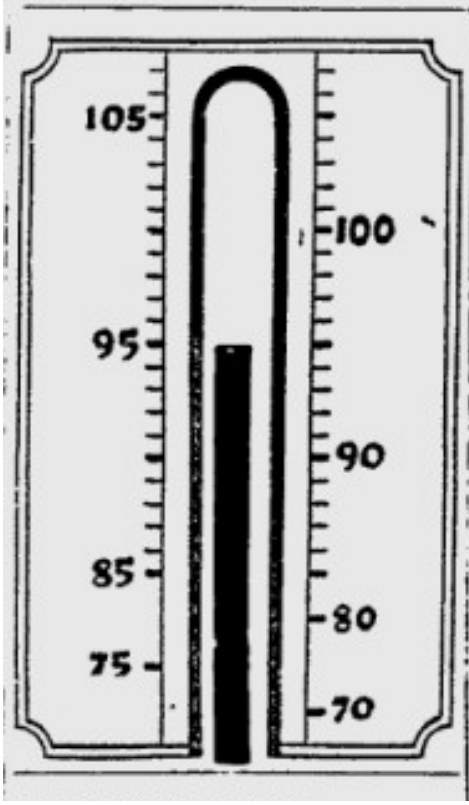
Three persons were reported drowned when the Austin dam gave way, earlier in the day. Coudersport and Port Allegheny were inundated. 40 0families were evacuated, and flood waters were rising as far away as Olean, N. Y.

Looks Like Hottest Day, With No Relief in Sight

Temperature May Pass 96 of Yesterday Downtown; Most of Country in Grip of Heat Wave, Weather Bureau Reports

The mercury threatened the day's all-time record today and Pittsburgh sweltered with no hope of immediate relief.

Continued high temperatures today and tonight were the forecast as the Weather Bureau announced a heat wave blanketing most of the nation had sent the temperature to 100 in Chicago.



Downtown Pittsburgh had a high of 96 degrees yesterday afternoon and it will be as hot or hotter today, the Weather Bureau said.

Nears 96 Degrees

Yesterday's official high was 94 at the Airport. Today the all-time July 18 record of 96 set 46 years ago in 1896 was being approached.

During the night the temperature never dropped lower than 75 Downtown and 77 at the Airport, and the mercury early in the morning began climbing past yesterday's marks.

At 9 a. m. it was 84 compared with 71 at 9 a. m. yesterday. By noon it was 92, compared with 84 at noon yesterday. After noon it pushed to 95.

Pittsburgh's all-time high temperature, still not in danger, was 103 degrees recorded on July 10, 1881.

92 Previous High

The highest previous official temperature this year, now left far behind, was the 92-degree mark set