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September 2008 Heavy Rains in Northeast Illinois: Meteorological Analysis and Impacts

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ABSTRACT

During 12-14 September 2008, an unlikely combination of abundant atmospheric moisture associated with the remnants of two tropical storms (Lowell from the Pacific Ocean and Ike from the Gulf of Mexico) and frontal lifting associated with a slow-moving cold front draped across the upper Mississippi River valley, produced record rainfall over parts of northern Illinois. Chicago's O'Hare airport set its all-time 24-h (midnight to midnight) rainfall record with 6.64 in. on 13 September. The heavy rains created historical flooding along most rivers in northern Illinois and northwestern Indiana, closed regional interstates, cancelled flights out of Chicago's Midway and O'Hare airports, placed many corn and soybean crops under water, and were linked to four deaths in the metropolitan area. A meso-/synoptic-scale analysis of the three-day period identified that heavy rains occurred over similar locations for extended periods. The unusual aspect of this event was the record-breaking 24-h precipitation totals in the absence of thunderstorm activity.

INTRODUCTION

Over the weekend of 12-14 September 2008, clouds above northern Illinois unleashed record rainfalls in what appears to be another case of a meteorological "perfect storm." This near-continuous rainfall quickly saturated soils leading to widespread flooding of creeks and rivers. By the morning of the 14th, Chicago's Deep Tunnel was completely full and the city was forced to release 90 billion gallons of storm runoff and untreated sewer water into Lake Michigan. Automobile, train, and aircraft traffic were severely restricted, isolating many of the Chicago metropolitan area's eight million residents.

Why was this event so unusual and worth further investigation? Heavy rainstorms causing two inches or more occur about once a year in Chicago (Huff and Angel 1989). When storms of this magnitude occur frequently over a couple of months they can lead to widespread impacts in the Chicago metropolitan region (Changnon and Westcott 2002).

Recent events (e.g., summer 1993 and July 1996) that produced significantly higher point rainfall totals in this region have created extreme social and economic impacts (Kunkel 1996; Changnon 1999; Changnon and Kunkel 1999). Most heavy rainstorms that occur in the upper Midwest are associated with thunderstorms (i.e., deep convection) that develop along a stationary or slow-moving frontal boundary (Huff 1978; Huff 1979; Changnon and Huff 1980; Kunkel 1996; Changnon and Kunkel 1999; Hilberg 2003). Climate records indicate that Chicago's Midway airport (a longer standing record than O'Hare) had only four previous cases of two consecutive days with ≥ 2-in precipitation totals in a 24-h period (midnight to midnight). Further analyses indicated that three of the four were associated with training thunderstorm clusters along an east-west quasi-stationary boundary draped across northern Illinois. Interestingly, this event was not associated with thunderstorms producing a range of hazardous weather, and, most who experienced this event never heard thunder. Instead, the event was characterized by an unusually long and continuous period when deep tropical moisture streamed into the region and was lifted by a slow-moving cold front. Analysis of the historical fourth case depicted analogous spatial and temporal meteorological features to those found during this event. Had this "perfect storm" occurred before? This paper investigates the meso- and synoptic-scale features present during this 72-h period, including a comparison to a similar historical occurrence, the related hydro-climatic elements of the event, and numerous impacts across the region.

DATA AND APPROACH

The meteorological analysis of the 12-14 September 2008 event examined a number of archived variables including those found in local and regional surface and upper-air analyses, and modeled historical data from the North American Regional Reanalysis (NARR). The NARR provides researchers with a consistent climate data suite for North America (Mesinger et al. 2006). The regional reanalysis is produced at high spatial and temporal resolutions (32-km, 45-layer, 3-hourly) and provides records from 1979 to present. NARR data were joined with National Weather Service (NWS) surface and upper-air data to construct spatio-temporal characteristics of the event, highlighting unusual features of the 72-hour duration storm.

Surface point rainfall totals from the NWS and the CoCoRaHs (Cifelli et. al 2005) network were used to plot daily and event rainfall totals in a geographic information system (GIS). Hourly METAR data were also examined to identify periods when precipitation may have been convective in nature (e.g., lightning in the METAR observations implies that thunderstorms were dominant around the time of the observation). Additionally, hydrographs and peak discharge values were examined in a GIS from various rivers to relate these values to impacts that occurred across Northeast Illinois.

RESULTS

Meso-/Synoptic Scale Analysis

An ingredients-based forecast approach (Doswell et al. 1996) utilized by Junker et al. (1999) showed that precipitable water (PW) anomalies were an important characteristic in identifying heavy rainfall events during the great Midwest floods of 1993 (e.g., the majority of heavy rain events were associated with PW values greater than an inch above

the norm). A rich feed of tropical moisture was already in the region around 0000 UTC on the 12th, as noted by a ridge of high surface dewpoints (≥ 65 °F) streaming as far north as southeastern Minnesota (Fig. 1). Deep-tropical moisture associated with remnants of a tropical system in the Eastern Pacific (Lowell) began streaming in from the southwest on the morning of the 12th. PW values had already started approaching 1.5 in., which was about 150 % of normal (Tuller 1968). Figure 2 shows a PW time-series of the event, as depicted from the two closest upper-air observation sites Davenport, IA (KDVN) and Lincoln, IL (KILX). Remarkably, PW values at KILX were able to persist above 2 in. for 60 hours! This was primarily due to the lack of forcing for the movement of the cold front with unidirectional vertical wind profiles aligning parallel to the surface cold front. This allowed for showers and a few thunderstorms to train along the same terrain for multiple days. Figure 3 shows slow progression of the surface cold front across the region for a 48-h period from 1200 UTC 12 September to 1200 UTC 14 September 2008. It appears that during a 24-h period from 1200 UTC 12 September to 1200 UTC 13 September, the cold front was more or less a stationary air mass boundary. However, the authors decided to demarcate this boundary on the surface maps as a cold front due to the nature of the front's progression during this period (e.g., the front traveled nearly 100 miles to the east during the day on the 12th and then was pushed westward with enhanced moisture associated with a nocturnal low-level jet stream during the early morning hours on the 13th). Secondly, a reinforcement of deep-tropical moisture related with remnants of Hurricane Ike from the Gulf of Mexico helped maintain a moist source region for the precipitation to draw on. The unidirectional nature of the vertical wind profile and deep tropical moisture associated with this event are revealed by atmospheric vertical profiles from KDVN and KILX (Fig. 4).

Many heavy rain events in northern Illinois are the result of thunderstorms. Another heavy rainfall event in northern Illinois on 17 July 1996 produced as much as 16 in. of rainfall in a 36-h period but was associated with intense convective activity (Changnon and Kunkel 1999). During that event, National Weather Service (NWS) WSR-88D radar near Chicago indicated reflectivities of 50 to 60 dBZ lasting for as long as 20 hours (Changnon and Kunkel 1999). In contrast, this event produced few reflectivities above 50 dBZ. Surface stations in northern Illinois reported thunder for a few hours, generally between 2200 LST 12 September and 0900 LST 13 September. Overall, METAR observations indicated that thunder was reported during only 10% to 20% of the event.

Hydro-Climatic Assessment

The rains of 12-14 September, 2008 were remarkable in terms of their hydro-climatic impacts across northern Illinois. A total of 87 daily precipitation records were set in Illinois during the three-day period. On 13 September, all-time daily precipitation records were set at Chicago O'Hare and at DuPage County Airport in West Chicago. Chicago O'Hare received 6.64 in. of rain (previous record 6.49 in.) while DuPage County Airport received 6.02 in. (previous record 3.47 in.). Elsewhere in Illinois, the cities of Keithsburg, Marietta, and Winchester also broke their all-time daily precipitation record on 13 or 14 September. Precipitation totals exceeded the 100-year return frequency across a 30-mile swath from Galesburg, IL northeast to northern Chicago (Fig.5). Precipitation totals for the event of greater than 10 inches were found across parts of DeKalb, Kane, DuPage and Cook counties in Illinois and Lake and Porter counties in Indiana (Figure 6).

Hourly rainfall data from Moline, IL and Chicago O'Hare were investigated to assess the temporal dimension of the event (Figure 7). Precipitation started around 1100 LST 12 September 2008 in western Illinois and continued for 33 continuous hours with no thunder reported in hourly observations. Heaviest amounts occurred during the late evening of 12 September and the early morning of 13 September, with 1.43 in. falling in the one-h period ending at 0000 LST 13 September 2008. At Chicago O'Hare, precipitation fell for 59 straight hours from approximately 0500 LST 12 September through 1500 LST 14 September 2008. Unlike the precipitation at Moline, thunder was reported during 2 of the 59 hours at Chicago O'Hare. While these two hours only account for 3% of the event, 2.25 inches of precipitation fell (about 26%) out of the 8.45 inches recorded by the hourly observations during the 59-h period. Again, the relative lack of thunder is remarkable given that most heavy precipitation events in the upper Midwest are associated with thunderstorms.

The extreme precipitation totals led to river flooding. Several rivers across the northern half of Illinois exceeding 100-year return interval streamflow (Figure 8). Rivers throughout northern Illinois rose rapidly on 13 and 14 September 2008 (Figure 9). In Wood Dale, IL, Salt Creek rose 8 feet in two days, from 7.36 feet on 12 September to 16.12 feet on 14 September. The Des Plaines, Kishwaukee, and West Branch DuPage rivers all rose 4 to 6 feet during the two-day period. The Fox River at Montgomery, East Branch DuPage River at Bolingbrook, and Illinois River at Morris, Ottawa, and LaSalle crested at their highest recorded stages. These rapid watershed rises also caused many area rivers to experience their highest peak discharge values.

Comparison to Similar Historical Event

Although heavy rainstorms (those producing ≥ 2 in. in a 24-h period) are not unusual in northern Illinois (Huff and Angel 1989), two consecutive days of ≥ 2 in. rainfall has only happened four other times in the climate record of Chicago's Midway Airport. Interestingly, one of these historical cases (12-13 September 1961) contained analogous spatial and temporal meteorological features to the 13-14 September 2008 event. Figure 10 shows a multi-panel comparison of 500-hPa heights and winds from similar temporal spacing periods during both events. With such similar upper-level features, it is no surprise that the surface tropical cyclones emerging out of the Gulf of Mexico also took similar tracks (Figure 11). The September 1961 event was not only ironic in its similar Julian day timing, but its meteorological similarities indicate that Illinois weather forecasters should be aware of this type of unusual and infrequent heavy rainfall event.

Regional Impacts

The record rainfall that occurred in northern Illinois created significant impacts across the region. President George W. Bush declared seven northeastern Illinois counties (Cook, DeKalb, DuPage, Grundy, Kane, LaSalle, and Will) disaster areas and by early October 2008, residents of these counties began to receive aid from state and federal sources (Hood, 2008). Four individuals died because of the flood-induced heavy rains.

The heavy rains lead to many flood-related issues across northern Illinois and northwestern Indiana. Communities along the Des Plaines, Chicago, DuPage, Fox, Little Calumet, Kankakee, and Illinois rivers experienced severe street and basement flooding. Over 2,000 homes were evacuated due to rising river levels and because flood levels were slow

to recede, they could not return to their homes for many days. In Cook County alone, more than 3,600 people were driven from their homes as water levels rose. After the waters slowly receded, residents were faced with cleaning up their homes and neighborhoods. Many lost most, if not all, possessions that were impacted by floodwaters. Large amounts of trash were found on city streets for weeks after the storm.

Chicago's Deep Tunnel, a system of large tunnels built under the city to hold 2.5 billion gallons of storm water runoff, filled by early Sunday (14 September 2008) forcing Chicago's Metropolitan Water Reclamation District to release storm runoff and untreated sewer water for the first time in six years. Four billion gallons of water an hour were released into Lake Michigan, and by end of the storm nearly 90 billion gallons of storm/sewer water was diverted to the Lake. This large release of untreated water led to concerns that sewage could find its way into water inlets. To counteract this potential problem Chicago and suburban communities that rely on Lake Michigan for drinking water enhanced chlorine amounts.

Transportation systems around the Chicago metropolitan area were highly impacted by the storm's floodwaters. As continuous rainfall occurred across the region Saturday into Sunday, a number of highways and interstates became overwhelmed with water. In northeastern Illinois parts of the Bishop Ford Freeway, I-90 and I-190 near O' Hare, and the Edens Expressway (I-94) north of downtown Chicago were closed for a number of hours. In northwestern Indiana, roads near the Little Calumet River were closed for several days. Interstates 65, and 80/94, a main east-west thoroughfare between the East Coast and Chicago, were flooded and remained closed to traffic until Tuesday, 16 September. Both Chicago airports delayed or canceled hundreds of flights over the weekend due to the almost continuous rainfall. Because of the interstate flooding, many individuals could not get to O'Hare either to pick up passengers or to catch flights. A number of metropolitan railroads had sections of track under water or impassible on Sunday. This slowed if not stalled the busiest freight railroad center in the United States for nearly 48 hours.

Agricultural areas outside of Chicago were also impacted. Mid-September is generally a period when corn and soybean crops are drying out before harvest. The heavy rains left fields saturated, and in many situations, large ponds developed. Luckily, most crops had matured by this point and the late growing season deluge did not significantly affect crop yields.

Additionally, the heavy rains impacted two major recreational areas in the region. Six Flags Great America theme park, located north of Chicago in Gurnee, and for the first time since it opened in 1934, Brookfield Zoo closed on Sunday. Many students received a three-day weekend as schools impacted by flooding were closed on Monday. North Park University (located near Chicago's north side) closed its dorms after losing power due to flooding.

SUMMARY

The 12-14 September 2008 rainstorm will be remembered for the unique meteorological conditions that created it, and the number of hydro-climatic records and flood-related

impacts across Northern Illinois. Anomalously high PW values associated with tropical moisture from two tropical storms (Lowell from the Pacific and Ike from the Gulf of Mexico) and a slow-moving cold front, were unique in the weather annuals for Chicago. Additionally, climate records indicate that a similar event occurred in 1961 with tropical moisture associated with Hurricane Carla. This unique and infrequent weather situation involving upper-level and surface meteorological features present, and their temporal progression, can be used by forecasters to anticipate non-convective heavy rainfall in Northern Illinois.

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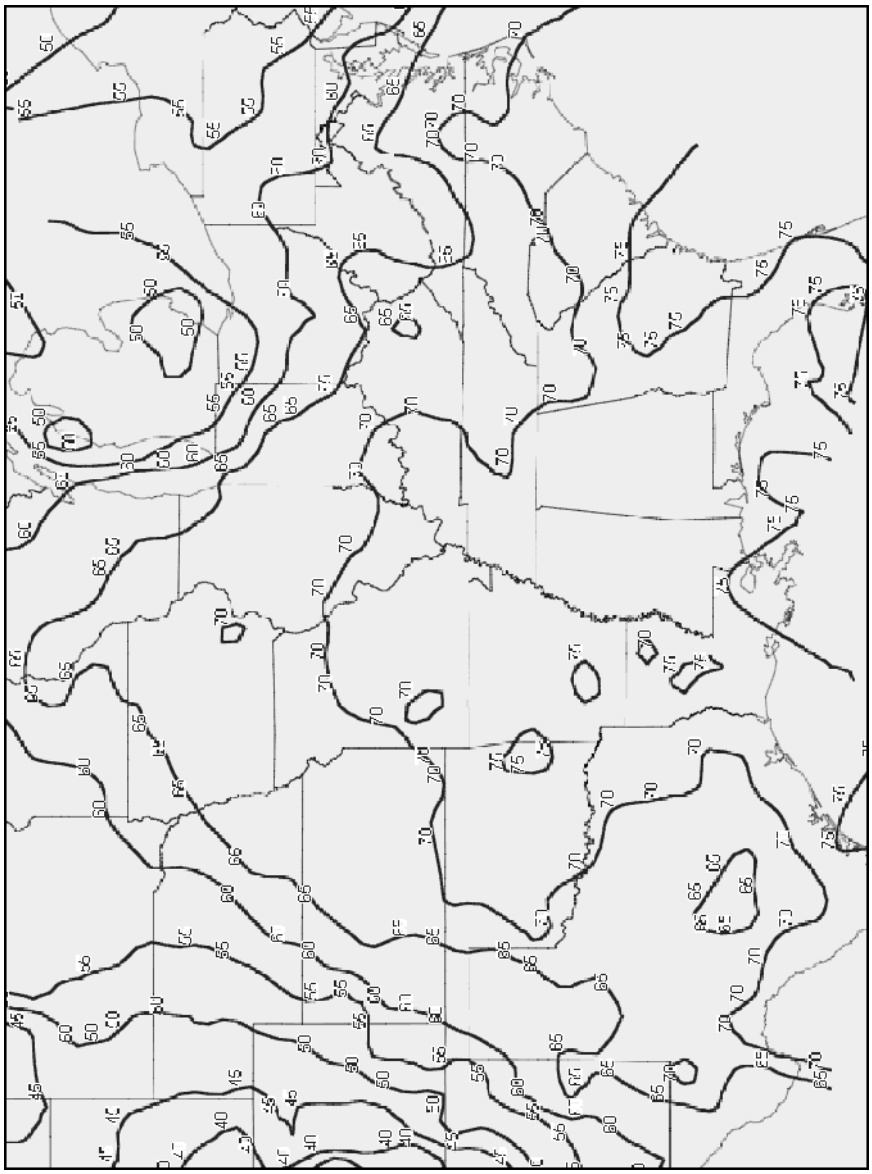


Figure 1. Surface isodrosotherms (solid, °F) valid at 0000 UTC 12 September 2008.

Figure 2. Time-series of precipitable water (PW, in) for the period 0000 UTC 12 September-0000 UTC 15 September 2008 for Davenport , IA and Lincoln, IL.

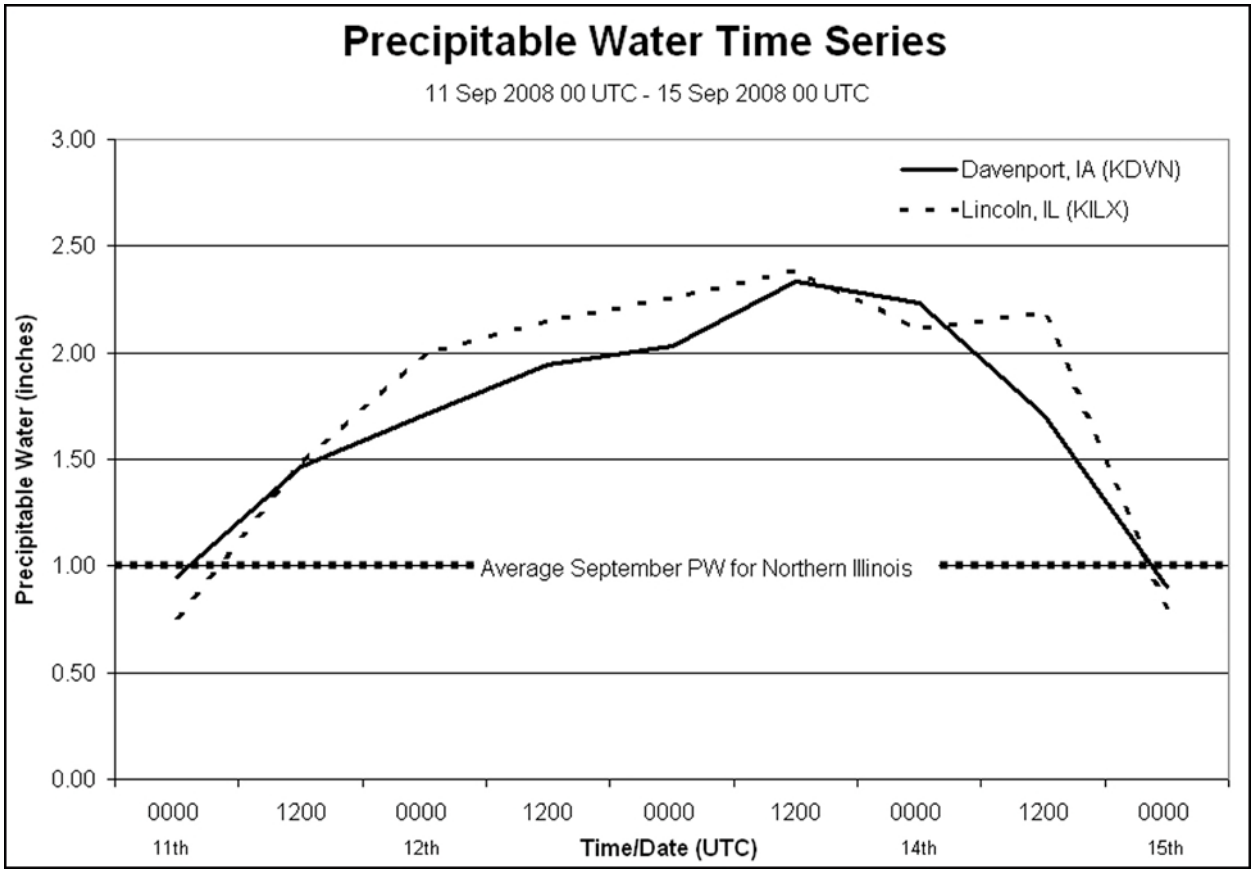
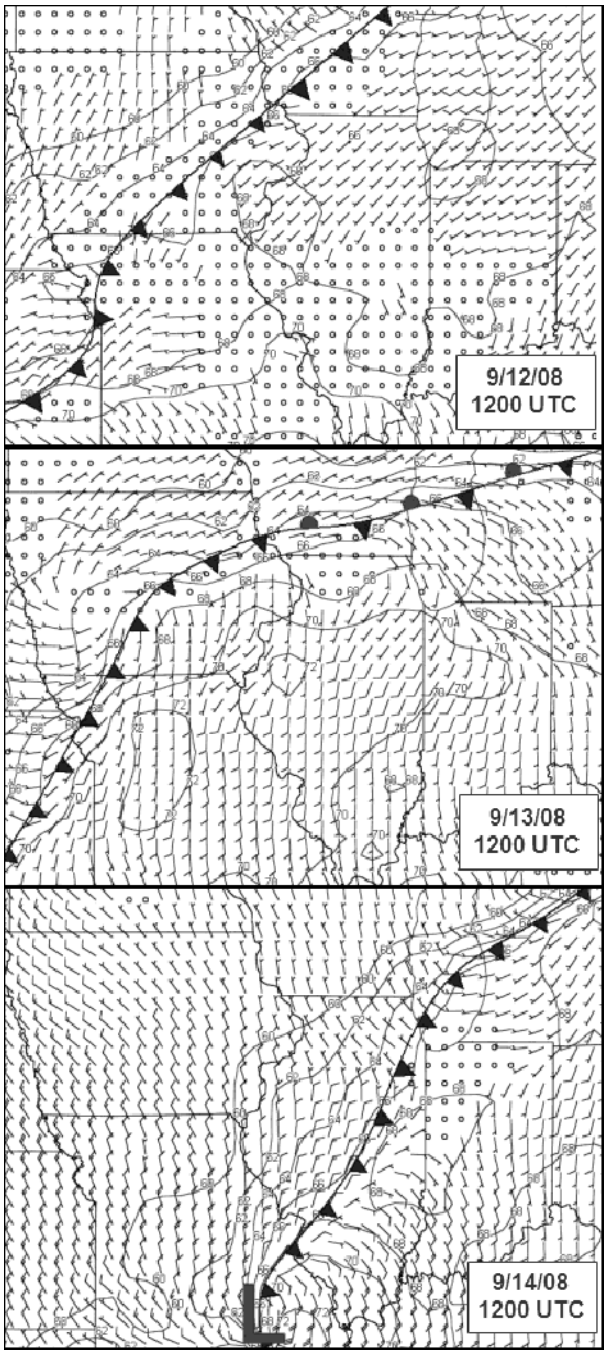


Figure 3. Surface isodrosotherms (solid, °F) and wind barbs (kt) valid at 1200 UTC 12 September 2008 (top), 1200 UTC 13 September 2008 (middle), and 1200 UTC 14 September 2008 (bottom).



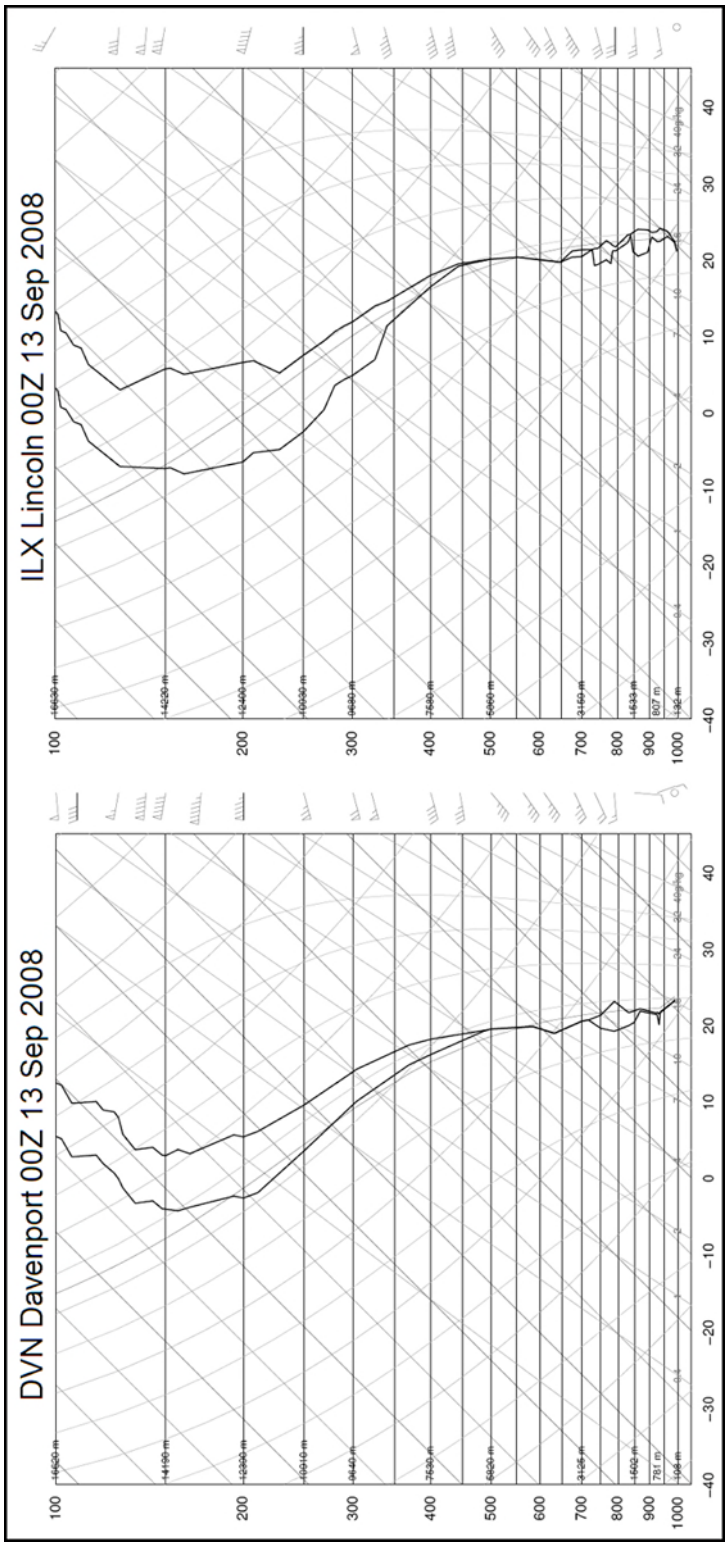


Figure 4. 0000 UTC 13 September 2008 soundings from KDVN (left) and KILX (right).

Figure 5. Rainfall return frequencies (icons/shading, years) over northern Illinois for the 12-14 September 2008 rainfall event (NOAA 2009).

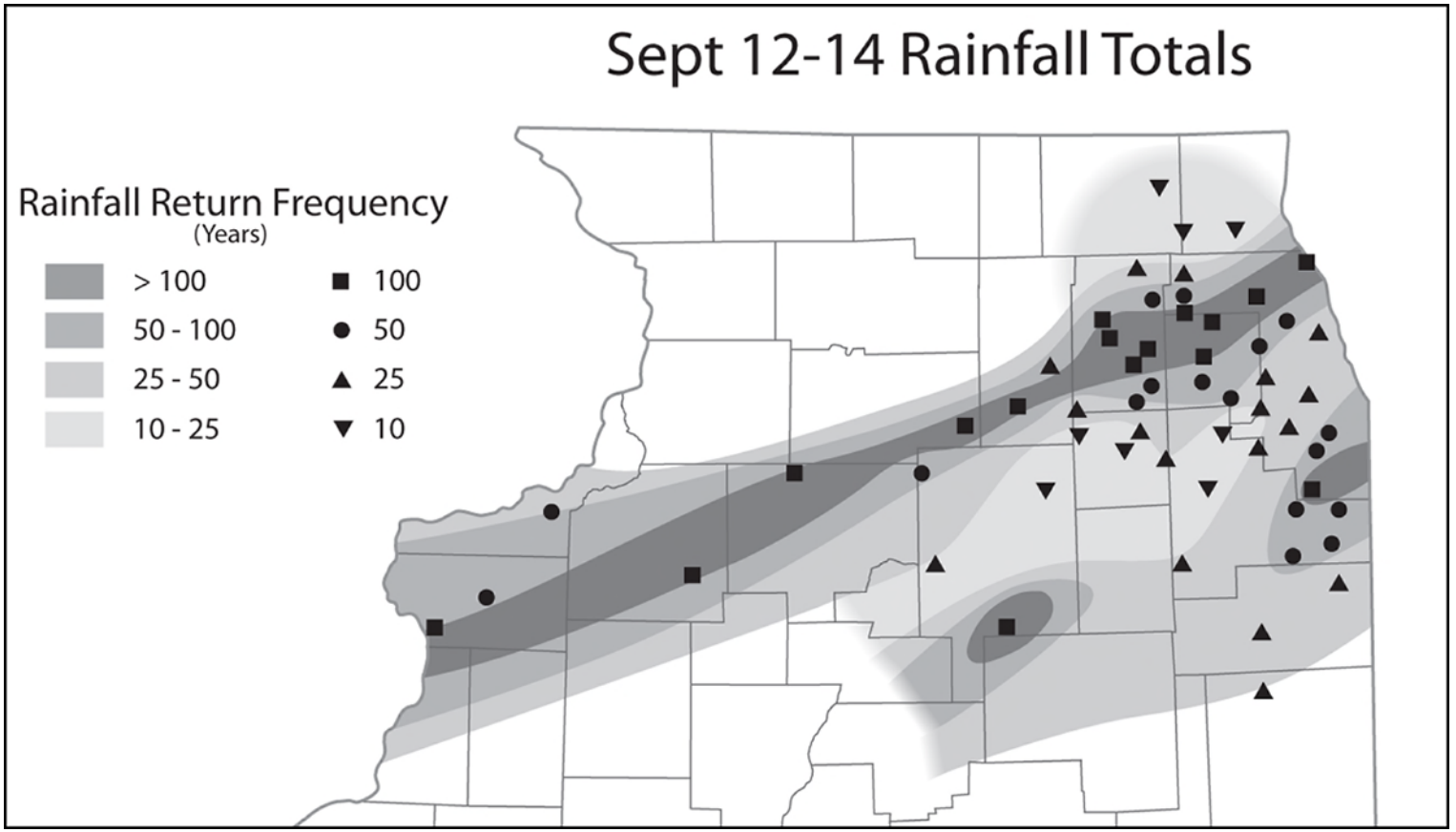


Figure 6. 12-14 September 2008 event total rainfall (in.) across northern Illinois and northwestern Indiana courtesy of National Weather Service and CoCoRaHS observations.

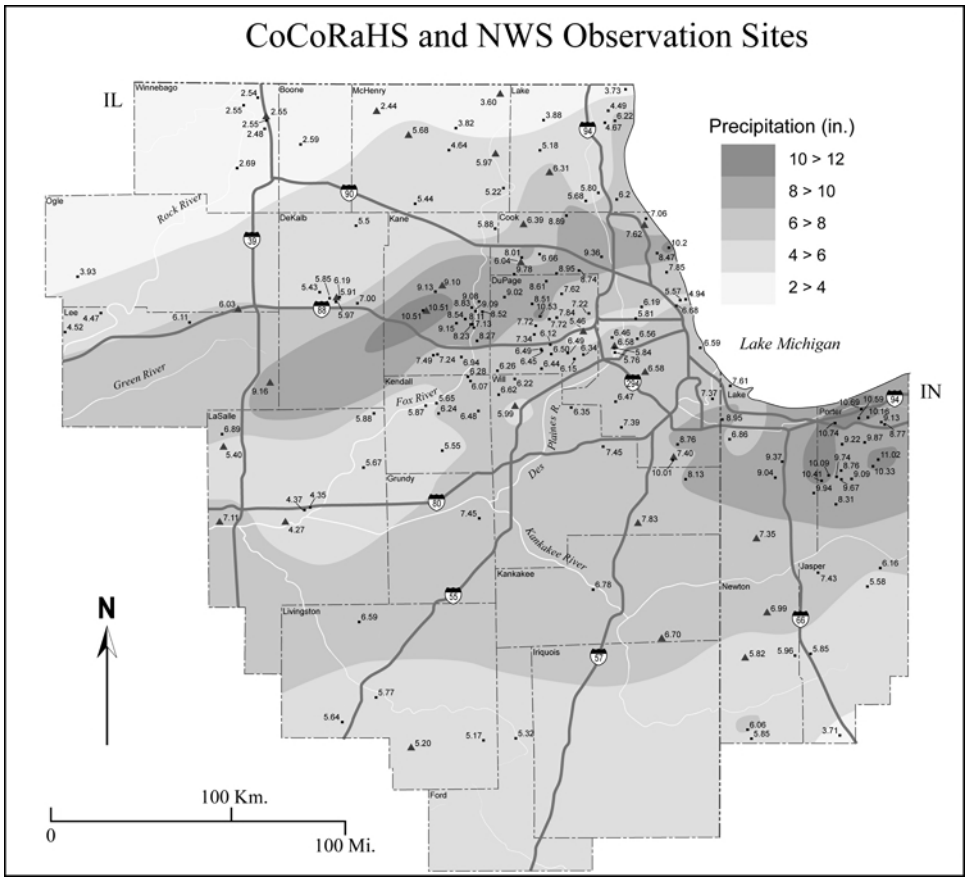


Figure 7. Hourly precipitation totals in inches from Moline, IL and Chicago O'Hare for the period from 0000 UTC 12 September to 0000 UTC 15 September 2008 (USGS 2009).

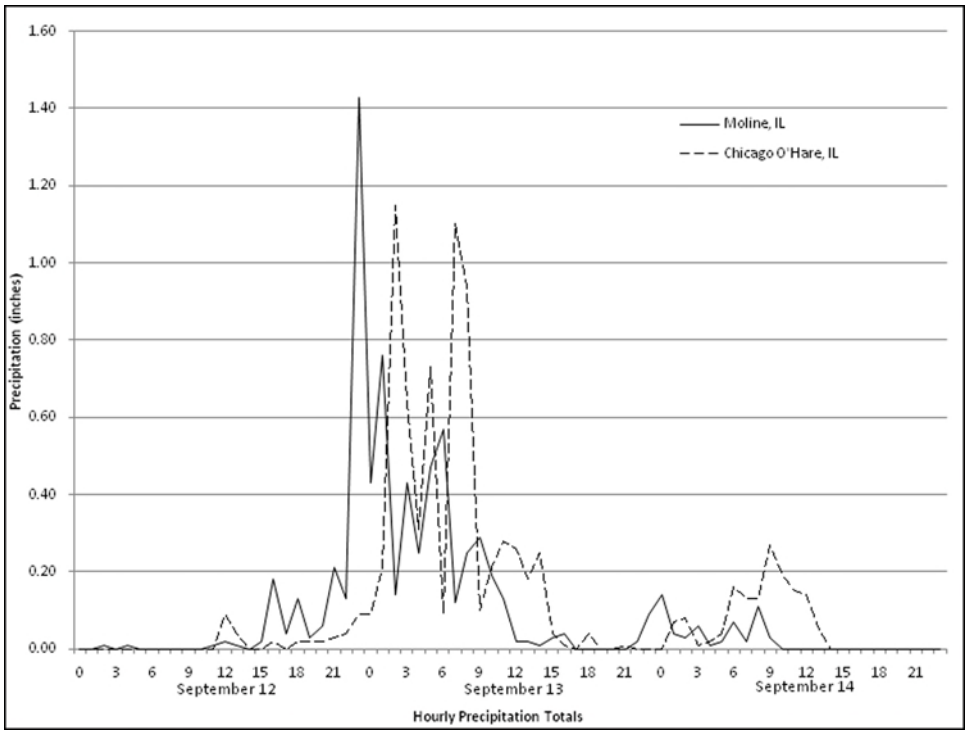


Figure 8. Peak streamflow return frequency (years) for northern Illinois for the 12-14 September 2008 rainfall event.

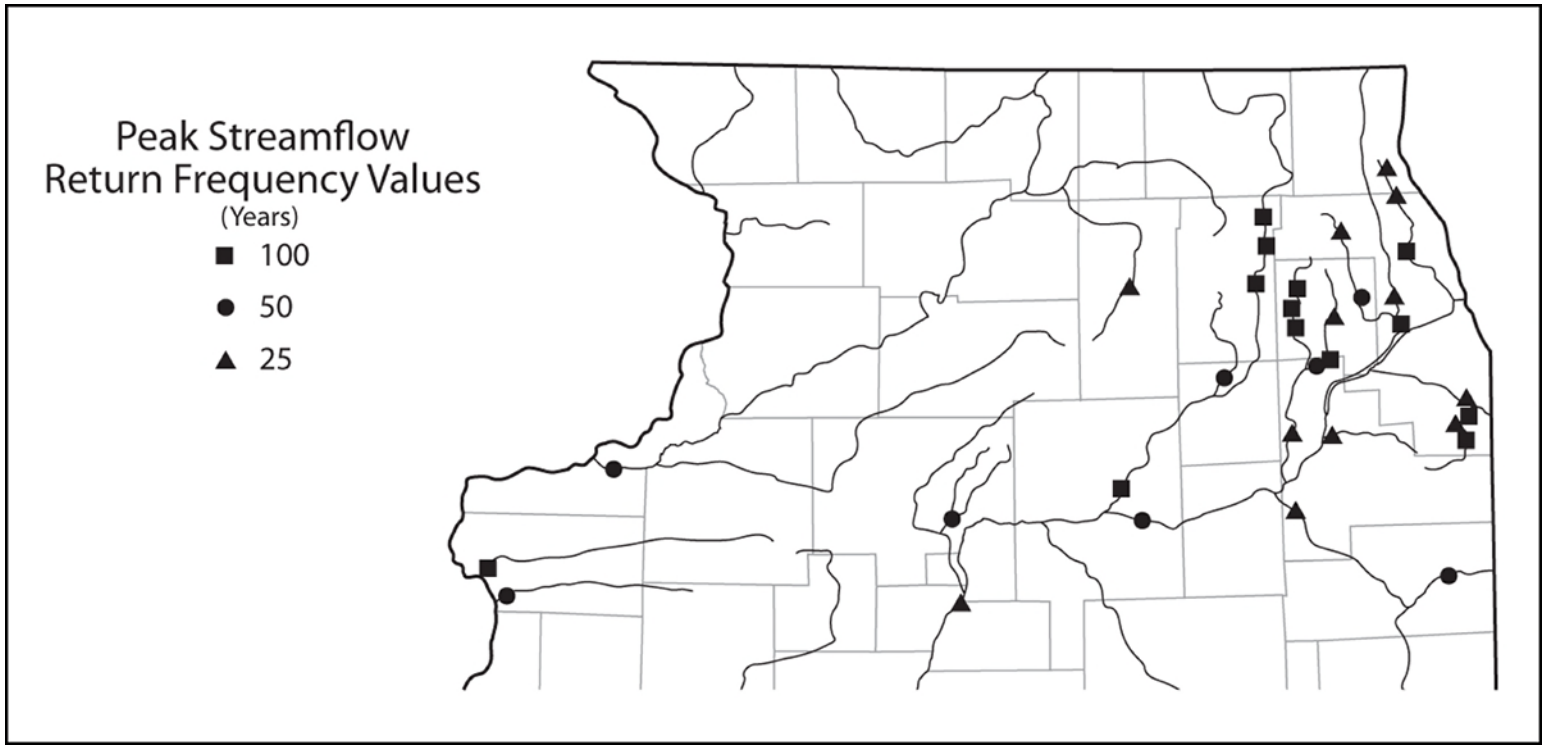


Figure 9. River stages (feet) for 10-20 September 2008 at various gauge sites in northeast Illinois.

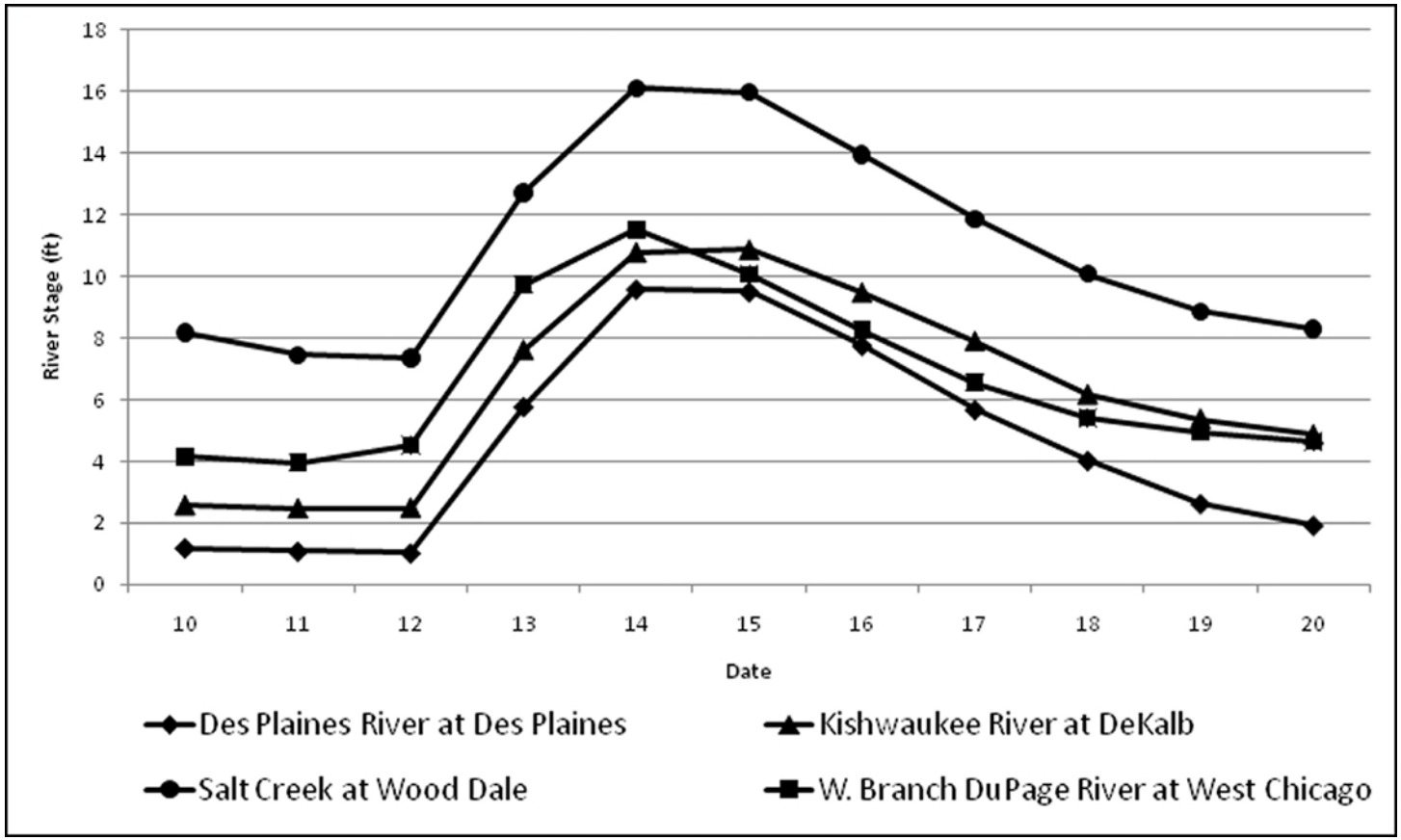


Figure 10. 500-hPa height thumbnail images for 11-14 September 1961 (left), and 12-15 September 2008 (right). Temporal progression is from top to bottom in 24-h intervals starting at 0000 UTC on the respective dates. Solid contours are geopotential height (ft on left, dam on right), dashed contours are isotherms (°C), and wind barbs are in kt. Images courtesy of NOAA's Daily Weather Map Series (left) and the Storm Prediction Center (right).

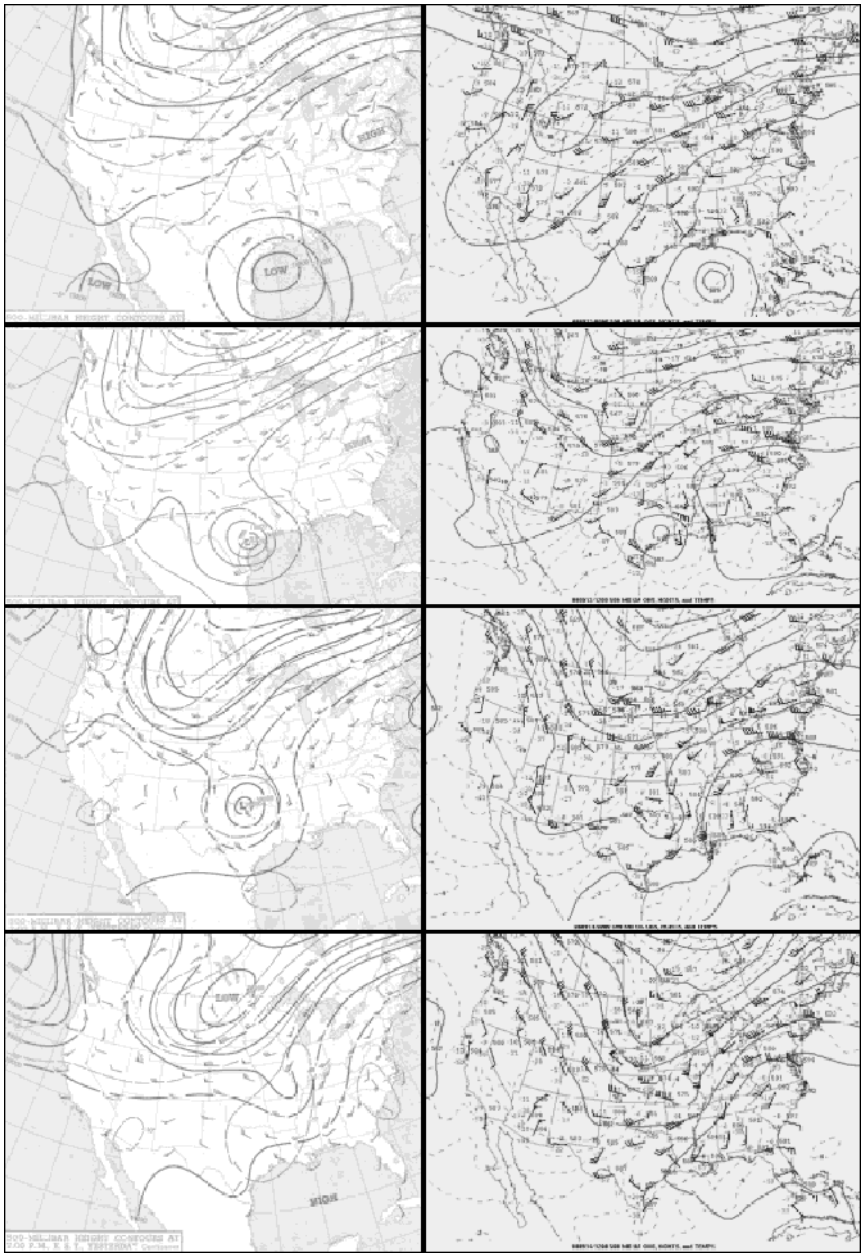


Figure 11. Surface cyclone tracks for Hurricane Ike (2008, dashed) and Hurricane Carla (1961, solid) that caused two inch or greater rainfall for two consecutive days at Chicago's Midway Airport.