A Meteorological Diagnosis of the Chicago Killer Heat Event of July 1995

1. INTRODUCTION

Perhaps the most deadly heat event to affect Chicago in its recorded history occurred during the period of July 12-15, 1995. A combination of record high temperatures and unusually high humidity produced "heat index" values which (officially) reached 125 deg F at Midway Airport during the afternoon of July 13th. The official high temperature of 104 deg F at O'Hare International Airport was just 1 degree shy of Chicago's official all-time record high of 105 set back on July 24, 1934. While Chicago's official high temperature of 104 was recorded at O'Hare Airport, Midway Airport reached 106 degrees on July 13, 1995.

Conditions in the neighborhoods of metropolitan Chicago were complicated by the widespread asphalt pavement, closely constructed buildings, and tendency for residents to be reluctant to open windows due to fear of crime. Consequently, heat-related deaths numbered over 700 during this period. This led to subsequent initiation of preventative programs by the city of Chicago, installation of a direct hot-line between the NWS Romeoville office and the city 'command center', as well as special heat warning criteria for the city of Chicago and Cook County.

Hot days in the Midwest during the summer months are not unusual. In fact, dewpoint levels which were experienced at Chicago are not unknown in rural areas where evapotranspiration from corn and soybeans elevates moisture greatly in favored synoptic situations (such as pooling along frontal zones). It is uncommon, however, for these extreme conditions to impact a major city and combined with air temperatures over 100 degrees.

In reviewing the meteorological data associated with this event, one can discern a number of factors which most likely played a role in producing the heat and humidity. As in most landmark events, a combination of forces or factors came together to create the excessive or unique conditions observed.

The intent of this article is to illustrate some of these extremes, diagnose the attendant synoptic forcing mechanisms and provide a discussion of the sequence of events which may have resulted in this deadly episode. It will concentrate on July 13th, the warmest day of the series. While these particular set of circumstances may never occur again "exactly" one can get insight from a post-analysis, an appreciation for the processes which contributed to the situation and use these as preparation for future heat related forecast challenges .

2. EVENT OVERVIEW

While the excessive heat of July 12-15 was unusually oppressive the month of July did not, on average, break a record. The average daily departure of temperature for the month was 4.4 degrees above the 30 year average. In comparison, the persistently hot summer of 1988 saw the average July temperature at plus 6.4 degrees.

Climatologically it is "normal" for an anticyclone to periodically build northward into the Plains during the summer months. Temperatures in excess of 100 degrees often accompany such events. In time the anticyclone retrogrades westward or drifts east depending upon the Northern Hemispheric-scale circulation regime. Northeast Illinois certainly feels the effects of an eastward migration. In many cases an on-shore flow from Lake Michigan (lake breeze) shields portions of metropolitan Chicago from the hottest conditions. In circumstances where the gradient flow is sufficient from the southwest, this cooling is negated and the heat is experienced city-wide. Such was the case here.

Observed minimum temperatures for July 13th were in the 70s over a wide area of the Midwest and Plains. A few locations remained above 80, including Chicago (ORD), LaCrosse, Wisc., St. Louis and Springfield Il.. In comparison, the "normal" high for Chicago during mid July is 86. Observed maximum temperatures for this day exceeded 100 westward to the high plains of Kansas and Nebraska. Unusual, however, is the northward extent of the 100 degF+ into northern Wisconsin.

Hourly surface observations indicated Rockford (RFD) never exceeded 100 degrees, but dewpoint temperature was at or above 80 degrees for all but two hours beginning at 13/1600UTC until 14/0400UTC. The dew point peaked at 83 degrees between 13/2300UTC and 14/0100UTC as the surface wind decreased late in the day.

In the immediate Chicago region, surface dew points held in the upper 70s to near 80 however the temperature exceeded 100 degF for several hours. Heat Index values were greater than 115 degrees for much of the midday and afternoon hours...reaching 125 degrees for the 2145UTC observation from Midway (MDW). In fact, the mercury remained at or above 100 degF at MDW for seven hours, from 13/1800UTC to 14/0100UTC. This extraordinary length may be partially due to the more urban location of the field.

The 'traditional' summer lake breeze was absent that day. This can be seen by noting the steady 10-15 knot southwest wind at all primary Chicago area reporting stations during the afternoon hours. For example, along the immediate Lake Michigan shore temperatures peaked well above 100 degF.at Meigs Field (CGX) remaining above 100 degF for 5 hours (1845UTC through 2345UTC)...peaking at 103 degF.

The Illinois Department of Nuclear Safety and Commonwealth Edison operate a series of meteorological monitoring towers at and west of the Zion Nuclear Power plant just south of the Wisconsin border. The plant is located on the Lake Michigan shore and 10-meter monitoring towers are located at the site, 2, 5 and 15 miles inland from this site. Time traces for this day reveal a steady offshore (west wind) flow and temperatures which peaked at about 102°F around 3 PM CST. Note the dew points remained between 75 and 80 degF much of the day. The lake water temperature, which is taken at an intake pipe a couple miles offshore, falls during the day probably reflecting up welling under the influence of a persistent offshore wind.

The 2 PM CDT (1900 UTC) observations for beach stations along the southwest Lake Michigan shore reflect again the widespread heat along the normally cooler lake shore. Two of these stations reported 105 with most others above 100. All winds are from the west-south quadrant except 3 sites.

Although the extreme heat, humidity and health consequences captured the public headlines, this event was also noted for its extremes in meteorology. For example the surface based lifted indices at mid afternoon (2000 UTC) were as low as -16 to -17 over a wide area from central Illinois to central Wisconsin. SHARP analysis of ILX and DVN soundings (not shown) revealed CAPE values near 8000 j/kg. These are levels associated with the day of the devastating Plainfield tornado in August of 1990. Despite the extreme instability, there was not a cloud in the hazy sky!

3. METEOROLOGICAL ASPECTS

The reason for lack of daytime cloud formation in spite of the extreme static instability can be seen in the DVN and ILX soundings. The DVN data from 13/1200 UTC reveals the expected sunrise surface inversion plus a mid level cap just above 500mb, which reflects the mid level synoptic subsidence of the anticyclone. A similar pattern is seen in the central Illinois ILX (Lincoln) sounding at 13/1200 UTC. The real story can be seen in the early evening soundings (14/0000 UTC) at both DVN and ILX. In each instance a marked stable layer continues just above 500mb while another can be seen between 850 mb and 900 mb. Both of these stable (inversion) zones show rapid drying at the top of the layer suggesting each was dynamically produced.

The center of the mid level anticyclone drifted across central Illinois during the day of July 13th. Compare 500-300 mb wind changes at ILX between 1200UTC and 0000UTC. It confirms the passage of the anticyclonic circulation during this period. Given the mid level anticyclone was the synoptic scale feature, the subsidence near 500mb is not unexpected. What is perhaps a bit unusual is the strength and continuity of the lower level inversion.

To get a broader notion of conditions contributing to this situation, consider the time sequence of 850mb data at 13/1200UTC and 14/0000UTC. The extreme temperatures near 30 deg C

evident over the Plains of Nebraska are gradually advected into northern Illinois over the 24 hour period. The greater than 30°C late afternoon readings partially reflect the higher elevation over the western High Plains. Therefore, even though 850mb temperatures "cool" into the upper 20s as they approach the Great Lakes this may be more a reflection of the receding terrain than cooler air.

Indicative of this heat is the surface map of 13/2100UTC. Scalloped areas are temperatures over 100 degF while dashed cover surface dew points at or above 80 degF. During this day there were a number of reports of dew points in the mid 80s over eastern Iowa and southwest Wisconsin. Surface isobars confirm the persistent southwest geostrophic wind gradient noted earlier.

Significant "contributing" factors to creation and maintenance of the heat bubble appear to fall on: advection of warm air from the west, addition of moisture from the corn fields over Iowa and western Illinois plus development of a lower level cap to prevent vertical mixing. To assess these processes we will look at the 850mb NGM model gridded data.

At 13/0000UTC the NGM 850mb initial analysis showed two wind maxima (speed > 20kts), one moving into western Iowa and the second exiting the central Lakes across Wisconsin. Isotherms (thick solid lines) bow eastward generally along the axis of defined winds while strong warm advection is across eastern Wisconsin and northern Lake Michigan (thin solid line). Subsidence ('positive' omega) is indicated by the dashed line and is broadly defined along the right flank of the wind axis. The shaded arrow denotes the lower level wind streak we will follow during the next 24 hours.

By 13/1200UTC the NGM 850mb initial analysis shows that nocturnal influences have increased wind speeds along the approaching 850mb wind maxima from near MSP to LBF to 40 kts. The bowed thermal structure (isotherms = thick solid line) is still along the jet axis and strong warm advection (thin solid line) has recentered westward over Wisconsin and northern Illinois. Significantly, the sinking motion along the right flank of the jet has also magnified, especially over eastern Iowa. The location of this subsidence pocket in the classic "right front" quadrant of the wind streak!

The 850mb data for 14/00UTC is a 12 hour NGM forecast (as opposed to previous initialized charts). It indicates the jet streak is progressing northeast, pushing the strongest warm advection zone with it into the upper Lakes. The 850mb temperatures are now well aligned with the strong wind axis. Note the location of the subsidence pocket. It has expanded in area and now covers all of northern Illinois and eastern Iowa with a strong signal. It is still along the right flank of the 850mb wind maxima but has shifted more toward the rear quadrant.

As a matter of comparison, the observed 850mb temperatures were greater than the model (NGM or ETA) initial and forecast values indicated. Model output under analyzed or under forecast the magnitude of the 850 mb temperature field during the extent of the period studied. That doesn't necessarily mean, however, the advective zones were misplaced in location.

The extent of the thermal bubble through the lower half of the atmosphere can be approximated by the 1000-500mb thickness. For example, the 850mb height field (solid) is overlaid by the 1000-500mb thickness at 13/1200UTC (from the NGM initial analysis). Here, one can get a sense of the translational nature of the warming through advection at 850mb superimposed upon the deeper layer mean temperature. In this case, and occasionally in the warm core anticyclone situations of the summer, the warmest temperatures at the surface generally correspond to the location (and migration) of the deep mean warm pool (thickness maxima).

Another look at 14/0000UTC conditions is viewed using the 850mb potential temperature and wind forecast, again from the 12hr NGM output. A clear association between the maximum temperature axis and core wind field can be seen.

Recall the subsidence zone along the right flank of this 850mb wind maxima described. It seems to have been reflected in the low level inversion which effectively capped the atmosphere over northern Illinois. A cross section taken along line A-B shows the vertical motion (thick solid line), theta lines (lighter solid) and core of wind >20kts as forecast 12hrs into the NGM model run, valid 14/0000 UTC. A core of sinking motion can be seen well below 850mb over extreme northern Illinois while the warmest air is to the north in Wisconsin (LaCross reached 108 deg F that day). The couplet between the sinking air south of the jet core and rising motion north (dashed line) suggests a vertical circulation associated with this feature. Over northern Illinois the 'cooler' air is sinking suggesting an indirect circulation. It strongly supports the low level subsidence inversion (with attendant drying) seen on the DVN and ILX soundings at 14/0000 UTC.

This low level (near boundary layer) capping acts as a "vertical pooling" mechanism whereby mixing is limited to a shallow depth, concentrating an already predisposed moist airmass to a (relatively) small vertical region.

4. SUMMARY

The four day period of July 12-15, 1995 provided one of the warmest and the most deadly series of hot days in Chicago history. The combination of extreme temperatures (up to 20 degrees above average during the warmest part of the year) and very high humidity levels, as measured by dew points exceeding 80 degrees, produced "heat index" values which peaked at 125 deg F. Undoubtedly higher levels were reached some pockets of the city.

Synoptic conditions resulted in a sustained southwest gradient wind. This prevented formation of a lake breeze and kept even the immediate Lake Michigan shoreline at 100 degrees or higher.

Surface heating and moisture levels also resulted in extreme levels of static instability over northern Illinois. Traditional indices such as the surface based lifted index reached -17 while CAPE values approached 8000 j/kg. Skies remained clear. Two inversions put an effective cap on any convection. One of these was located near 500mb while another was found just below 850mb. Both had time and space continuity.

The higher level inversion could be attributed to subsidence related to the synoptic scale anticyclone. The lower inversion appeared dynamically related to a 850mb wind maxima which rotated northeast from the Plains into central Wisconsin. Subsidence along the right flank of this feature was continuous over time as it progressed into northern Illinois during the day of the 13th. The sinking motion also tended to increase in magnitude and areal extent during the 24 hour period of July 13/0000UTC to July 14/0000UTC.

As in most singular meteorological events, a number of dynamic and thermodynamic forcing mechanisms need to become coincident to create the observed conditions. In this case a nominally hot air mass seems to have been augmented further by low level subsidence which, in turn, capped any convective tendencies. The resulting full sunshine during the climatologically warmest time of the year and shallow mixing layer created a deadly combination of heat and humidity which were superimposed upon the sociological aspects of a densely populated major metropolitan area.