CLIMATE CHANGE AND YOUR HEALTH

Heat in the Heartland

60 Years of Warming in the Midwest

TECHNICAL APPENDIX

Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions

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Overview

WITH OUR FOCUS ON DANGERous heat, we limited our study period to the summer months: June, July, and August. We obtained data from airport weather stations for each city, which provided information on afternoon and nighttime air and dew point temperatures, air pressure, cloud cover, and wind velocity. We analyzed these records from the start of recorded data at the National Climatic Data Center, which varied from city to city as follows: Chicago (1948), Cincinnati (1948), Detroit (1959), Minneapolis (1945), and St. Louis (1946). We analyzed data from this starting year through 2011.

We also selected smaller cities in relatively close proximity to the large cities, to investigate urban heat island effects, as the smaller cities would be less susceptible to those effects. The same type of air mass usually affects both a large city and its smaller counterpart. We analyzed the smaller cities in the same manner as the primary cities, except that we did not investigate three-day-or-longer runs of oppressive weather in the smaller cities. The airport locations where data were collected in these five cities tended to be located in relatively rural areas at least 10 miles from the city center. Research suggests that temperatures drop off dramatically as you travel 10 miles or more beyond a city's borders. (Urban Heat Islands 2012; Dixon and Mote 2003).[1] We reasoned that in these small cities, any urban heat island effects would be considerably smaller than comparable effects in major urban areas such as Chicago or Detroit. Therefore, if a large city shows a warming trend that's not apparent in its smaller counterpart, that trend is more likely a result of an urban heat island effect. On the other hand, if both the small and large cities in each pair experienced a similar warming trend, that trend is unlikely to be due primarily to urban heat island effects.When both urban centers and more rural locations were found to have experienced similar warming trends, we could determine that trends in Midwest city heat are not likely due to urbanization effects alone.

To explore air mass trends, we turned to an established and widely used weather classification model known as the Spatial Synoptic Classification or SSC (Greene et al. 2011; Sheridan and Dolney 2003; Sheridan 2002). Incorporating all the variables in the airport data, we classified each day's weather into one of six types of air masses. We then focused on three types of air mass: hot and humid (moist tropical, as well as an extreme subset of this air mass known as moist tropical+), hot and dry (dry tropical), and cool and dry (dry polar). The dry tropical (DT) and moist tropical+ (MT+) air masses are most important to human health, as they are associated with an increased risk of heat-related deaths (Sheridan and Kalkstein 2004).

This SSC presents several advantages. By evaluating actual past weather situations (air masses) instead of just temperatures, we could obtain a more detailed picture of the changes in weather patterns that midwesterners have actually experienced over the last 60 years. This approach also allowed us to consider variables other than temperature that can affect human health, such as humidity.

The SSC is a discrete classification: every day must be placed in a particular category. In most cases, a day closely resembles the typical character of its category. However, a borderline situation may occur on a minority of days: that is, a given day has characteristics between two types of air masses.

The SSC typically uses a probability procedure to classify such days as a type of air mass (see Sheridan 2002). For example, a day with a 55 percent probability of being in the moist tropical class and a 45 percent probability of being in the moist moderate class will be classified as MT. About two-thirds of days have probabilities above 90 percent of being a particular type of air mass (Sheridan, oral communication).

That is particularly true of DT and MT+ air masses—those on which we focused our analysis. Because these days are on the hottest and driest (DT) or hottest and most humid (MT+) portions of the SSC spectrum, they have a higher probability of landing squarely in one of those categories. That is particularly true of days that undermine health in the target cities, as those are the most extreme cases of these oppressive air masses.

The Summary of Statistics for Cities section (below) shows trends in the frequency and characteristics of different types of air masses for each city, and whether those trends are statistically significant. In some cities, dry tropical air masses were uncommon enough that we could not perform proper statistical tests, as the data did not meet the tests of normality. Our data on dry tropical characteristics also have gaps in years when no such air masses occurred. We could still determine trends over the entire period, but could not perform proper significance testing.

As the tables and figures below reveal, more moist tropical trends are significant than dry tropical trends. That is partly because the cities we studied had many more moist tropical days, so the resulting trends met tests of normality.

To begin to assess uncertainty in the trends, we calculated standard errors for each estimated slope, representing the accuracy we expected from that slope. This is a measure of accuracy, with a low value indicating greater accuracy. These standard errors (labeled SE) are reported for the five major cities but not the smaller cities.

The data used to determine the trend lines represent average values for each year. The number of data points for each year varies, given that a particular type of air mass occurs with varying frequency. For example, MT+ air masses can occur on 20 percent of all summer days one year and 5 percent of all summer days another year. Mean temperatures and dew points at 3:00 p.m. and 3:00 a.m. are therefore based on a different number of days each year. We did not weight the means to account for these year-to-year variations in the number of data points.

Previous research has shown that several days in a row of oppressive heat affect human health (Kalkstein et al. 2011). Other studies have associated a run of at least three consecutive days of elevated temperature and humidity with increased mortality (Basu and Samet 2002). We therefore wanted to determine if longer stretches of dangerously hot days have become more common.

To evaluate dangerous heat waves, we investigated whether three-day runs of very hot, humid (moist tropical+) and hot, dry (dry tropical) days—in any combination—have increased.[2] We focused on combinations of those two types of air masses because they are most associated with effects on human health (Sheridan and Kalkstein 2004). We also investigated changes in the frequency of three-day runs of uncomfortably hot, humid (moist tropical) weather.

Finally, we investigated whether each type of air mass has itself become warmer or more humid in a given city. By investigating both air and dew point temperatures, we hoped to gain a sense of how relative humidity trends have changed over time. Specifically, we looked at the 3:00 p.m. and 3:00 a.m. air temperature and dew point temperature (representing daytime and nighttime values) for each type of air mass during each summer day on record. Because nighttime heat relief is an important factor in heat stress, distinguishing between daytime and nighttime trends can reveal stress on a population during periods of elevated heat.[3]

The temperature measurements of 3:00 a.m. and 3:00 p.m. provide a snapshot of the impact of thermal stress for both daytime (high solar input) hours and overnight hours (Sheridan and Kalkstein 2004). There are some limitations introduced with using a 3:00 a.m to 3:00 p.m. time frame (i.e., relying on one specific time to characterize a longer time period). However, it was decided that 3:00 a.m. and 3:00 p.m. measurements would be a sufficient choice of exposure because our study is not directly examining health-related outcomes but instead characterizing the air masses associated with negative health outcomes. Other factors that contributed to our selection were also data availability, resource and time constraints, and the fact that the 3:00 a.m./3:00 p.m. time frame is an inherent piece of the SSC classification system, along with other temperature variables (Sheridan and Kalkstein 2004).

The data used in this analysis extend back to the late 1940s when digital records first became available. Thus our analysis does not capture the warm decade of the 1930s, which may have influenced trends over the last century. However, both the 1920s and 1940s were relatively cool and the decade of the 1930s likely represents an anomalous period of warmth in the longer trend of gradual warming. Therefore extending the data set further back in time would likely not greatly affect the trends we found. There have also been some recent studies looking at a "warming hole" in the central United States (Kunkel et al 2006). This was a period of cooling over portions of the Midwest during the years 1940 to 1979, with warming resuming over the recent decades. There may be implications for the trends we found; however, the identified "hole" was based on temperatures over the entire year. In addition, the cooling trends were strongest during winter months, and less pronounced in summer, which is the basis for this air mass study. Also, more recent trends of the past few decades may be more relevant to assessing public health impacts and responses to dangerous heat. Over the past few decades a "noticeable" warming trend has been observed for the Midwest (USGCRP 2009).

Summary of Statistics for Cities

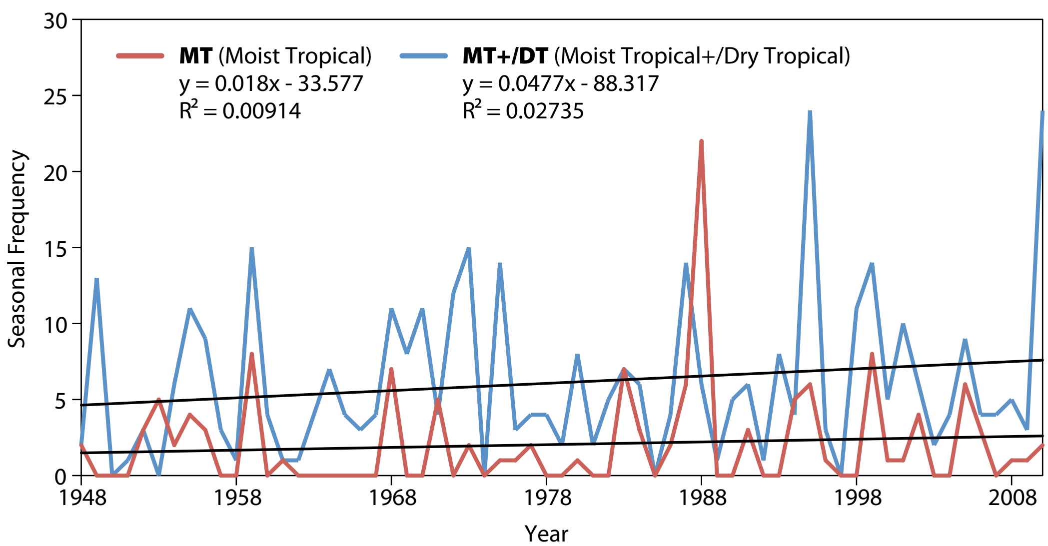
This section shows data on three types of air masses: dry polar (DP), dry tropical (DT), and moist tropical+ (MT+).

Summary of Statistics for Summer Season (JJA): Chicago, IL

	Air Mass Frequency			Air Mass Characteristics											
				3 p.m. Air Temp.			3 p.m. Dew Point			3 a.m. Air Temp.			3 a.m. Dew Point		
Air Mass	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE
DP	-0.119	0.135*	0.038	-0.007	0.021	0.006	-0.031	0.0140*	0.010	0.027	0.144*	0.009	0.007	0.008	0.010
DT	0.024	0.011	0.029	-0.005	0.002	0.015	-0.033	0.040	0.025	0.023	0.040	0.017	0.025	0.026	0.023
MT+	0.038	0.025	0.031	-0.002	0.001	0.009	-0.001	0.000	0.009	0.015	0.060^	0.078	0.007	0.009	0.009

*Significant at the 0.05 level ^Significant at the 0.10 level

3-Day Consecutive Runs: Chicago, IL



Note: Represents data from 1948 to 2011.

Summary of Statistics for Summer Season (JJA): Peoria, IL (paired with Chicago)

	Air Mass Frequency		Air Mass Characteristics							
			3 p.m. Air Temp.		3 p.m. Dew Point		3 a.m. Air Temp.		3 a.m. Dew Point	
Air Mass	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2
DP	-0.069	0.065*	0.011	0.042	0.016	0.028	0.023	0.106*	0.030	0.125*
DT	0.010	0.001	-0.004	0.002	-0.019	0.010	0.026	0.034	0.010	0.003
MT+	0.094	0.152*	-0.007	0.012	0.021	0.056^	0.013	0.077*	0.018	0.096*

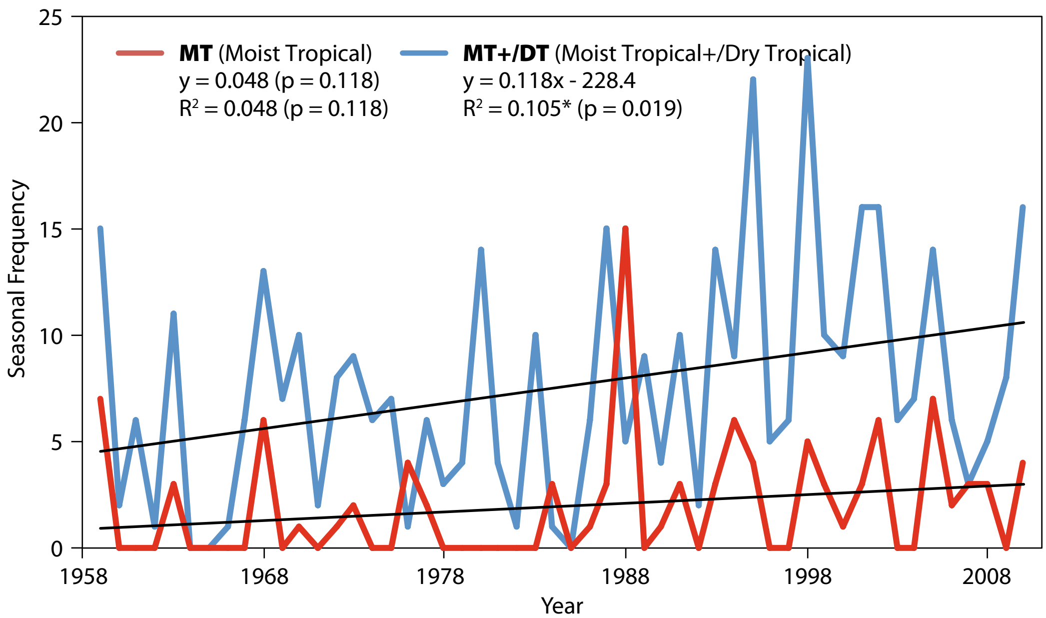
*Significant at the 0.05 level ^Significant at the 0.10 level

Summary of Statistics for Summer Season (JJA): Detroit, MI

	Air Mass Frequency			Air Mass Characteristics											
				3 p.m. Air Temp.			3 p.m. Dew Point			3 a.m. Air Temp.			3 a.m. Dew Point		
Air Mass	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE
DP	-0.203	0.332*	0.063	-0.020	0.088*	0.009	-0.012	0.015	0.015	0.028	0.105*	0.012	0.010	0.011	0.014
DT	0.065	0.050^	0.040	-0.028	0.085^	0.017	-0.054	0.084^	0.032	0.046	0.173*	0.018	0.011	0.006	0.025
MT+	0.066	0.059^	0.037	0.002	0.000	0.015	0.007	0.007	0.013	0.023	0.098*	0.010	0.027	0.110*	0.010

*Significant at the 0.05 level ^Significant at the 0.10 level

3-Day Consecutive Runs: Detroit, MI



Note: Represents data from 1959 to 2011.

Summary of Statistics for Summer Season (JJA): Toledo, OH (paired with Detroit)

	Air Mass Frequency		Air Mass Characteristics							
			3 p.m. Air Temp.		3 p.m. Dew Point		3 a.m. Air Temp.		3 a.m. Dew Point	
Air Mass	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2
DP	-0.167	0.344*	0.000	0.000	-0.011	0.013	0.023	0.054^	0.006	0.004
DT	0.048	0.038	0.004	0.004	0.005	0.001	0.038	0.057^	0.050	0.092*
MT+	0.063	0.048^	0.001	0.000	0.021	0.069^	0.014	0.043	0.021	0.062^

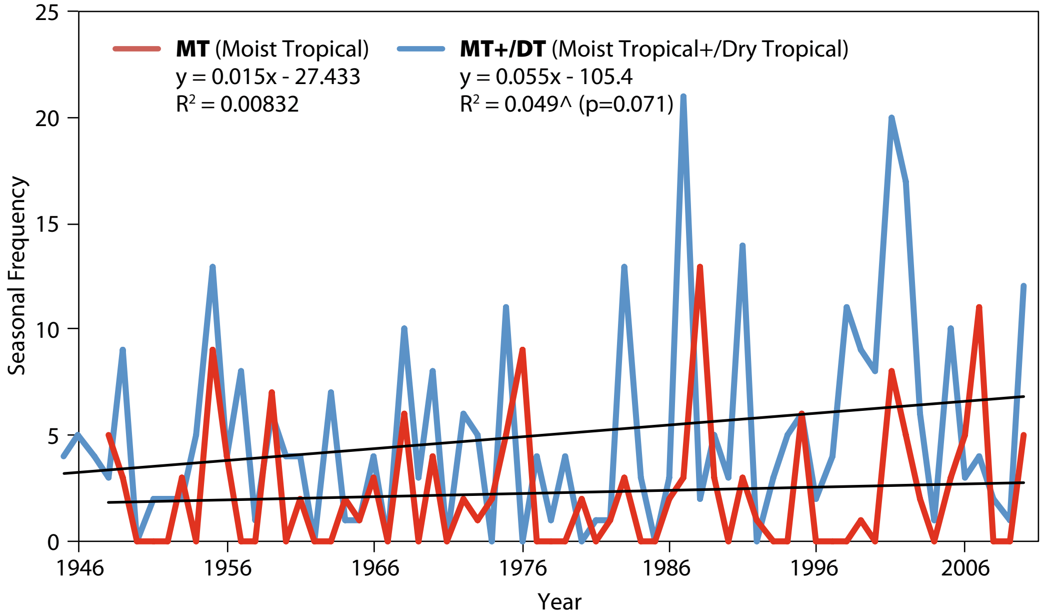
*Significant at the 0.05 level ^Significant at the 0.10 level

Summary of Statistics for Summer Season (JJA): Minneapolis, MN

	Air Mass Frequency			Air Mass Characteristics											
				3 p.m. Air Temp.			3 p.m. Dew Point			3 a.m. Air Temp.			3 a.m. Dew Point		
Air Mass	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE
DP	-0.068	0.057^	0.034	-0.010	0.035	0.007	-0.016	0.034	0.011	0.009	0.017	0.009	-0.007	0.009	0.009
DT	0.045	0.022	0.037	-0.027	0.101*	0.011	-0.014	0.008	0.020	-0.007	0.004	0.015	-0.012	0.007	0.012
MT+	0.025	0.016	0.024	-0.012	0.018	0.011	0.005	0.004	0.010	0.014	0.050^	0.009	0.019	0.071*	0.009

*Significant at the 0.05 level ^Significant at the 0.10 level

3-Day Consecutive Runs: Minneapolis, MN



Note: Represents data from 1945 to 2011.

Summary of Statistics for Summer Season (JJA): Rochester, MN (paired with Minneapolis)

	Air Mass Frequency		Air Mass Characteristics							
			3 p.m. Air Temp.		3 p.m. Dew Point		3 a.m. Air Temp.		3 a.m. Dew Point	
Air Mass	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2
DP	0.022	0.004	-0.003	0.006	0.038	0.211*	0.022	0.148*	0.019	0.085*
DT	-0.058	0.067*	-0.018	0.041	-0.052	0.067	0.001	0.000	-0.011	0.005
MT+	0.012	0.005	-0.016	0.059^	0.010	0.017	0.000	0.000	0.009	0.022

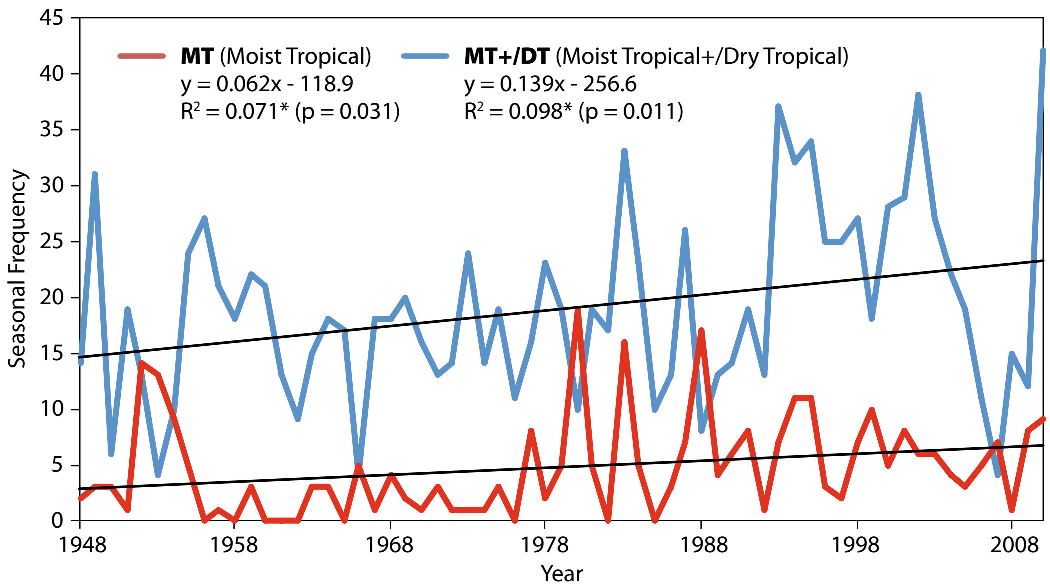
*Significant at the 0.05 level ^Significant at the 0.10 level

Summary of Statistics for Summer Season (JJA): St. Louis, MO

	Air Mass Frequency			Air Mass Characteristics											
				3 p.m. Air Temp.			3 p.m. Dew Point			3 a.m. Air Temp.			3 a.m. Dew Point		
Air Mass	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE
DP	-0.060	0.098*	0.023	-0.001	0.000	0.008	0.012	0.016	0.013	0.030	0.149*	0.009	0.026	0.093*	0.010
DT	0.000	0.000	0.047	-0.002	0.000	0.013	0.029	0.060^	0.016	0.038	0.132*	0.014	0.066	0.181*	0.020
MT+	0.152	0.243*	0.034	-0.011	0.052^	0.006	0.009	0.028	0.007	0.018	0.176*	0.005	0.005	0.014	0.006

*Significant at the 0.05 level ^Significant at the 0.10 level

3-Day Consecutive Runs: St. Louis, MO



Note: Represents data from 1946 to 2011.

Summary of Statistics for Summer Season (JJA): Columbia, MO (paired with St. Louis)

	Air Mass Frequency		Air Mass Characteristics							
			3 p.m. Air Temp.		3 p.m. Dew Point		3 a.m. Air Temp.		3 a.m. Dew Point	
Air Mass	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2
DP	-0.118	0.135*	0.021	0.137*	0.047	0.165*	0.026	0.166*	0.037	0.187*
DT	0.024	0.011	0.053	0.273*	0.049	0.108*	0.031	0.111*	0.034	0.114*
MT+	0.038	0.025	-0.008	0.020	0.015	0.058^	-0.003	0.008	0.011	0.088*

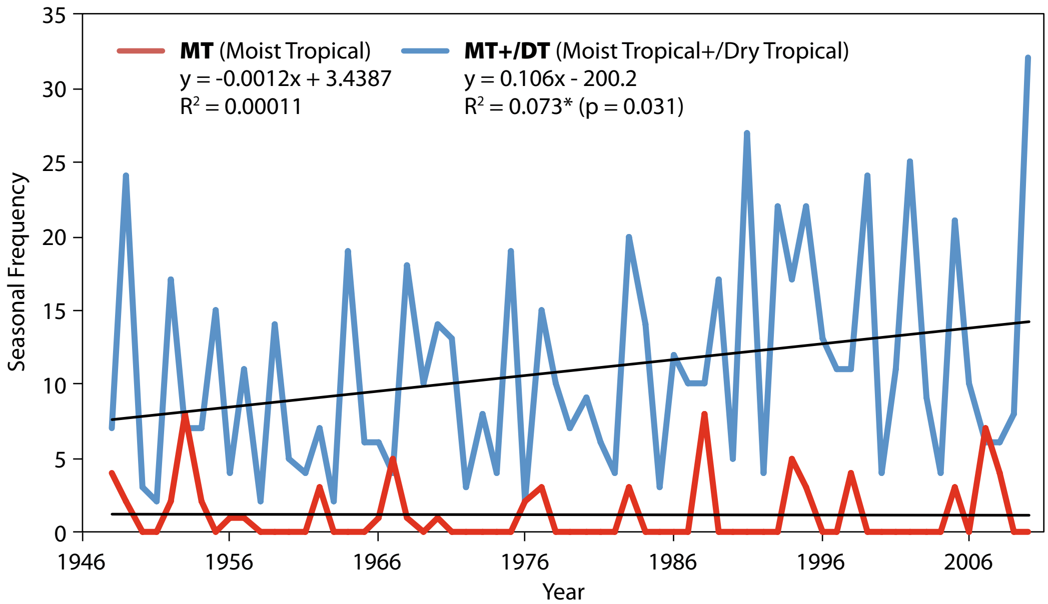
*Significant at the 0.05 level ^Significant at the 0.10 level

Summary of Statistics for Summer Season (JJA): Cincinnati, OH

	Air Mass Frequency			Air Mass Characteristics											
				3 p.m. Air Temp.			3 p.m. Dew Point			3 a.m. Air Temp.			3 a.m. Dew Point		
Air Mass	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE
DP	-0.033	0.019	-0.033	0.002	0.001	0.008	0.013	0.016	0.014	-0.001	0.000	0.011	-0.003	0.001	0.012
DT	-0.029	0.013	0.032	-0.007	0.015	0.012	-0.018	0.023	0.022	0.005	0.008	0.011	-0.010	0.022	0.014
MT+	0.033	0.054^	0.018	-0.010	0.013	0.014	0.000	0.000	0.000	0.002	0.001	0.010	-0.006	0.008	0.010

*Significant at the 0.05 level ^Significant at the 0.10 level

3-Day Consecutive Runs: Cincinnati, OH



Note: Represents data from 1948 to 2011.

Summary of Statistics for Summer Season (JJA): Lexington, KY (paired with Cincinnati)

	Air Mass Frequency		Air Mass Characteristics							
			3 p.m. Air Temp.		3 p.m. Dew Point		3 a.m. Air Temp.		3 a.m. Dew Point	
Air Mass	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2
DP	-0.035	0.023	0.000	0.000	0.020	0.040^	0.013	0.038	0.006	0.005
DT	-0.009	0.001	0.002	0.001	-0.002	0.000	0.019	0.031	0.000	0.000
MT+	0.038	0.068*	-0.016	0.042	-0.003	0.003	0.009	0.021	-0.002	0.002

*Significant at the 0.05 level ^Significant at the 0.10 level

A Deeper Look at the Summary Statistics

THE TABLES BELOW SHOW THE FREquencies and characteristics of types of air masses that affect health (DT and MT+) for large cities and their paired smaller cities. The tables also show results for cooler dry polar (DP) air masses, which provide relief from hotter and more humid weather. The slopes are derived from a simple linear regression of the time series data, along with the coefficient of determination (R^2) values.

Our study focused on city-level trends. As geographic regions under analysis become smaller, the results usually become more variable. This can be seen when comparing globally averaged temperature trends with continental and regional temperature trends. One advantage of using air masses to analyze heat trends is that this approach incorporates more data, which can reduce variability and allow trends at the city level to emerge.

Air Mass Frequency

Some 50 percent of the trends in air mass frequency we found for large and smaller cities were significant at the 0.10 level or less, with 10 of those trends statistically significant at the 0.05 level. Overall, the hottest and most humid air masses became more common in both the large and smaller cities, while cooler summer air masses became less common. That is consistent with an overall warming trend in the Midwest. A few trends did not fit this pattern, but that often occurs when analyzing data at the city level across a large geographic region.

Air Mass Characteristics

Overall, trends in air temperatures and dew points were more variable than trends in the frequencies of air masses. Yet many of the former were statistically significant. Overnight 3:00 a.m. air temperatures and dew points showed some of the strongest warming and moisture trends. Trends in afternoon air and dew point temperatures were less pronounced. These results support other findings that the diurnal cycle—the difference between daytime and nighttime temperatures—narrows with climate change. That is, nights are warming faster than days.

Urban Heat Island Effects

Trends in the frequencies of summer air masses generally moved in the same direction in both larger cities and their smaller counterparts. A few results did not conform to this pattern, but again, that is expected across a large region.

Some of the smaller cities showed stronger trends in the frequencies of oppressive summer air masses than their parent cities. That finding provides more support for the conclusion that trends in the Midwest are not due entirely to urban heat island effects, but to a larger change in climate.

Like air mass frequencies, trends in air mass characteristics were somewhat similar between larger and smaller cities. These characteristics were more variable overall, and a larger percentage were not statistically significant.

Notably, when trends varied between pairs of cities, the trends were weak and not statistically significant in one or both cities. When trends were significant, both the larger city and the paired smaller city showed agreement.

Summary of Statistics for Summer Season (JJA): Chicago, IL

	Air Mass Frequency			Air Mass Characteristics											
				3 p.m. Air Temp.			3 p.m. Dew Point			3 a.m. Air Temp.			3 a.m. Dew Point		
Air Mass	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE
DP	-0.119	0.135*	0.038	-0.007	0.021	0.006	-0.031	0.0140*	0.010	0.027	0.144*	0.009	0.007	0.008	0.010
DT	0.024	0.011	0.029	-0.005	0.002	0.015	-0.033	0.040	0.025	0.023	0.040	0.017	0.025	0.026	0.023
MT+	0.038	0.025	0.031	-0.002	0.001	0.009	-0.001	0.000	0.009	0.015	0.060^	0.078	0.007	0.009	0.009

*Significant at the 0.05 level ^Significant at the 0.10 level Disagreement in trend between large and paired smaller city
Agreement in trend between large and paired smaller city DP = dry polar DT = dry tropical MT+ = moist tropical+

Summary of Statistics for Summer Season (JJA): Peoria, IL (paired with Chicago)

	Air Mass Frequency		Air Mass Characteristics							
			3 p.m. Air Temp.		3 p.m. Dew Point		3 a.m. Air Temp.		3 a.m. Dew Point	
Air Mass	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2
DP	-0.069	0.065*	0.011	0.042	0.016	0.028	0.023	0.106*	0.030	0.125*
DT	0.010	0.001	-0.004	0.002	-0.019	0.010	0.026	0.034	0.010	0.003
MT+	0.094	0.152*	-0.007	0.012	0.021	0.056^	0.013	0.077*	0.018	0.096*

*Significant at the 0.05 level ^Significant at the 0.10 level Disagreement in trend between large and paired smaller city
Agreement in trend between large and paired smaller city DP = dry polar DT = dry tropical MT+ = moist tropical+

Summary of Statistics for Summer Season (JJA): Detroit, MI

	Air Mass Frequency			Air Mass Characteristics											
				3 p.m. Air Temp.			3 p.m. Dew Point			3 a.m. Air Temp.			3 a.m. Dew Point		
Air Mass	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE
DP	-0.203	0.332*	0.063	-0.020	0.088*	0.009	-0.012	0.015	0.015	0.028	0.105*	0.012	0.010	0.011	0.014
DT	0.065	0.050^	0.040	-0.028	0.085^	0.017	-0.054	0.084^	0.032	0.046	0.173*	0.018	0.011	0.006	0.025
MT+	0.066	0.059^	0.037	0.002	0.000	0.015	0.007	0.007	0.013	0.023	0.098*	0.010	0.027	0.110*	0.010

*Significant at the 0.05 level ^Significant at the 0.10 level Disagreement in trend between large and paired smaller city
Agreement in trend between large and paired smaller city DP = dry polar DT = dry tropical MT+ = moist tropical+

Summary of Statistics for Summer Season (JJA): Toledo, OH (paired with Detroit)

	Air Mass Frequency		Air Mass Characteristics							
			3 p.m. Air Temp.		3 p.m. Dew Point		3 a.m. Air Temp.		3 a.m. Dew Point	
Air Mass	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2
DP	-0.167	0.344*	0.000	0.000	-0.011	0.013	0.023	0.054^	0.006	0.004
DT	0.048	0.038	0.004	0.004	0.005	0.001	0.038	0.057^	0.050	0.092*
MT+	0.063	0.048^	0.001	0.000	0.021	0.069^	0.014	0.043	0.021	0.062^

*Significant at the 0.05 level ^Significant at the 0.10 level Disagreement in trend between large and paired smaller city
Agreement in trend between large and paired smaller city DP = dry polar DT = dry tropical MT+ = moist tropical+

Summary of Statistics for Summer Season (JJA): Minneapolis, MN

	Air Mass Frequency			Air Mass Characteristics											
				3 p.m. Air Temp.			3 p.m. Dew Point			3 a.m. Air Temp.			3 a.m. Dew Point		
Air Mass	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE
DP	-0.068	0.057^	0.034	-0.010	0.035	0.007	-0.016	0.034	0.011	0.009	0.017	0.009	-0.007	0.009	0.009
DT	0.045	0.022	0.037	-0.027	0.101*	0.011	-0.014	0.008	0.020	-0.007	0.004	0.015	-0.012	0.007	0.012
MT+	0.025	0.016	0.024	-0.012	0.018	0.011	0.005	0.004	0.010	0.014	0.050^	0.009	0.019	0.071*	0.009

*Significant at the 0.05 level ^Significant at the 0.10 level Disagreement in trend between large and paired smaller city
Agreement in trend between large and paired smaller city DP = dry polar DT = dry tropical MT+ = moist tropical+

Summary of Statistics for Summer Season (JJA): Rochester, MN (paired with Minneapolis)

	Air Mass Frequency		Air Mass Characteristics							
			3 p.m. Air Temp.		3 p.m. Dew Point		3 a.m. Air Temp.		3 a.m. Dew Point	
Air Mass	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2
DP	0.022	0.004	-0.003	0.006	0.038	0.211*	0.022	0.148*	0.019	0.085*
DT	-0.058	0.067*	-0.018	0.041	-0.052	0.067	0.001	0.000	-0.011	0.005
MT+	0.012	0.005	-0.016	0.059^	0.010	0.017	0.000	0.000	0.009	0.022

*Significant at the 0.05 level ^Significant at the 0.10 level Disagreement in trend between large and paired smaller city
Agreement in trend between large and paired smaller city DP = dry polar DT = dry tropical MT+ = moist tropical+

Summary of Statistics for Summer Season (JJA): St. Louis, MO

	Air Mass Frequency			Air Mass Characteristics											
				3 p.m. Air Temp.			3 p.m. Dew Point			3 a.m. Air Temp.			3 a.m. Dew Point		
Air Mass	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE	Slope	R^2	SE
DP	-0.060	0.098*	0.023	-0.001	0.000	0.008	0.012	0.016	0.013	0.030	0.149*	0.009	0.026	0.093*	0.010
DT	0.000	0.000	0.047	-0.002	0.000	0.013	0.029	0.060^	0.016	0.038	0.132*	0.014	0.066	0.181*	0.020
MT+	0.152	0.243*	0.034	-0.011	0.052^	0.006	0.009	0.028	0.007	0.018	0.176*	0.005	0.005	0.014	0.006

*Significant at the 0.05 level ^Significant at the 0.10 level Disagreement in trend between large and paired smaller city
Agreement in trend between large and paired smaller city DP = dry polar DT = dry tropical MT+ = moist tropical+

Summary of Statistics for Summer Season (JJA): Columbia, MO (paired with St. Louis)

	Air Mass Frequency		Air Mass Characteristics							
			3 p.m. Air Temp.		3 p.m. Dew Point		3 a.m. Air Temp.		3 a.m. Dew Point	
Air Mass	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2
DP	-0.118	0.135*	0.021	0.137*	0.047	0.165*	0.026	0.166*	0.037	0.187*
DT	0.024	0.011	0.053	0.273*	0.049	0.108*	0.031	0.111*	0.034	0.114*
MT+	0.038	0.025	-0.008	0.020	0.015	0.058^	-0.003	0.008	0.011	0.088*

*Significant at the 0.05 level ^Significant at the 0.10 level Disagreement in trend between large and paired smaller city
Agreement in trend between large and paired smaller city DP = dry polar DT = dry tropical MT+ = moist tropical+

Summary of Statistics for Summer Season (JJA): Cincinnati, OH

	Air Mass Frequency			Air Mass Characteristics											
				3 p.m. Air Temp.			3 p.m. Dew Point			3 a.m. Air Temp.			3 a.m. Dew Point		
Air Mass	**Slope**	**R^2**	**SE**	**Slope**	**R^2**	**SE**	**Slope**	**R^2**	**SE**	**Slope**	**R^2**	**SE**	**Slope**	**R^2**	**SE**
DP	-0.033	0.019	-0.033	0.002	0.001	0.008	0.013	0.016	0.014	-0.001	0.000	0.011	-0.003	0.001	0.012
DT	-0.029	0.013	0.032	-0.007	0.015	0.012	-0.018	0.023	0.022	0.005	0.008	0.011	-0.010	0.022	0.014
MT+	0.033	0.054^	0.018	-0.010	0.013	0.014	0.000	0.000	0.000	0.002	0.001	0.010	-0.006	0.008	0.010

*Significant at the 0.05 level ^Significant at the 0.10 level Disagreement in trend between large and paired smaller city
Agreement in trend between large and paired smaller city DP = dry polar DT = dry tropical MT+ = moist tropical+

Summary of Statistics for Summer Season (JJA): Lexington, KY (paired with Cincinnati)

	Air Mass Frequency		Air Mass Characteristics							
			3 p.m. Air Temp.		3 p.m. Dew Point		3 a.m. Air Temp.		3 a.m. Dew Point	
Air Mass	**Slope**	**R^2**	**Slope**	**R^2**	**Slope**	**R^2**	**Slope**	**R^2**	**Slope**	**R^2**
DP	-0.035	0.023	0.000	0.000	0.020	0.040^	0.013	0.038	0.006	0.005
DT	-0.009	0.001	0.002	0.001	-0.002	0.000	0.019	0.031	0.000	0.000
MT+	0.038	0.068*	-0.016	0.042	-0.003	0.003	0.009	0.021	-0.002	0.002

*Significant at the 0.05 level ^Significant at the 0.10 level Disagreement in trend between large and paired smaller city
Agreement in trend between large and paired smaller city DP = dry polar DT = dry tropical MT+ = moist tropical+

A Closer Look at All Data for Chicago

THE FREQUENCY OF A GIVEN TYPE of air mass clearly varies from year to year. However, when we analyzed the long-term record, temporal trends emerged. To illustrate our process, we include all tables and figures for Chicago, which has weather records dating back to 1948, and Peoria, IL, its smaller counterpart (next section).

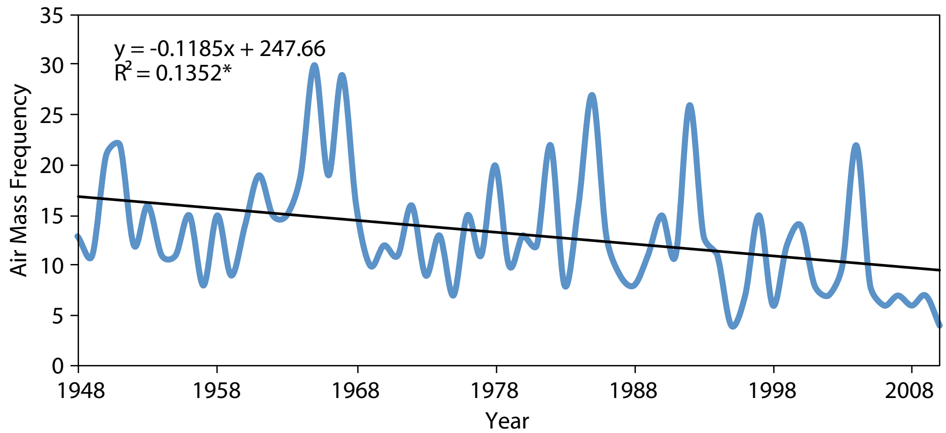
As the trend line shows, Chicago now sees about seven very hot, humid (moist tropical+) days each summer, compared with slightly more than five such days in 1948, on average. While this trend is not statistically significant, it is important, as it shows a consistent increase over time. The Peoria results, in contrast, show a very strong trend in the frequency of these days, with a statistically significant p-value of less than 0.05.

Summary of Statistics: Chicago, IL

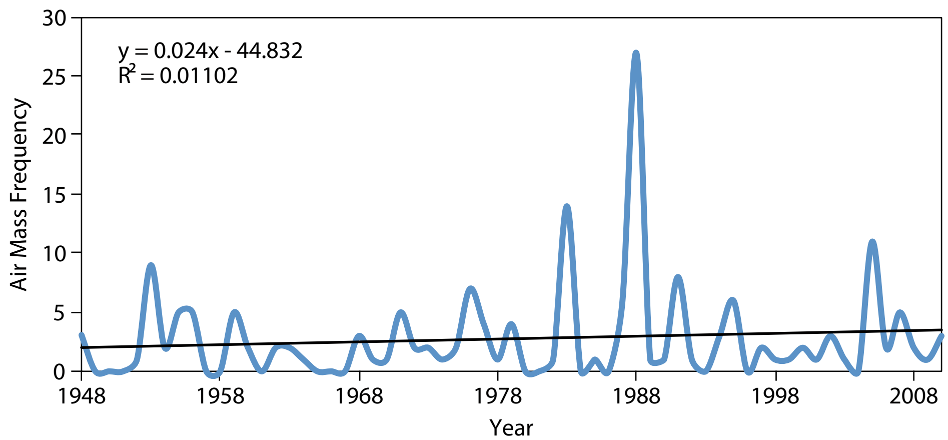
	Air Mass Frequency			Air Mass Characteristics											
Summer Season (JJA)				**3 p.m. Air Temp.**			**3 p.m. Dew Point**			**3 a.m. Air Temp.**			**3 a.m. Dew Point**		
Air Mass	**Slope**	**R^2**	**SE**	**Slope**	**R^2**	**SE**	**Slope**	**R^2**	**SE**	**Slope**	**R^2**	**SE**	**Slope**	**R^2**	**SE**
DP	-0.119	0.135*	0.038	-0.007	0.021	0.006	-0.031	0.0140*	0.010	0.027	0.144*	0.009	0.007	0.008	0.010
DT	0.024	0.011	0.029	-0.005	0.002	0.015	-0.033	0.040	0.025	0.023	0.040	0.017	0.025	0.026	0.023
MT+	0.038	0.025	0.031	-0.002	0.001	0.009	-0.001	0.000	0.009	0.015	0.060^	0.078	0.007	0.009	0.009

*Significant at the 0.05 level ^Significant at the 0.10 level DP = dry polar DT = dry tropical MT+ = moist tropical+

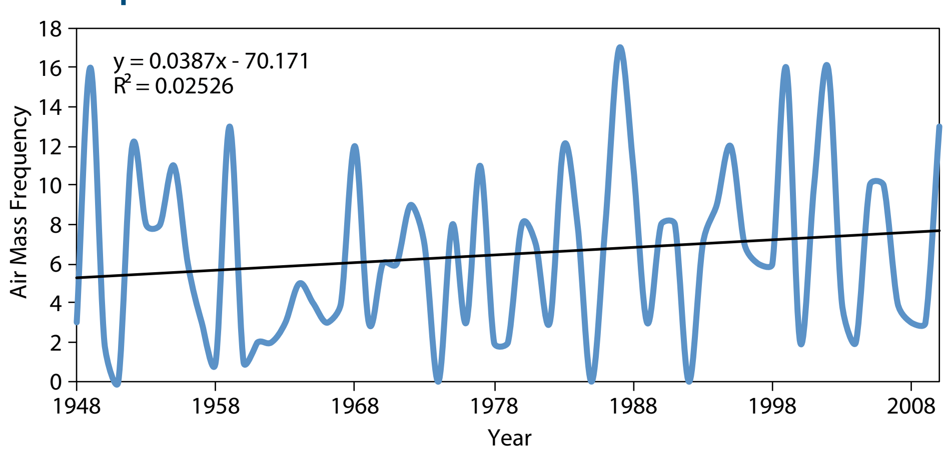
Dry Polar



Dry Tropical



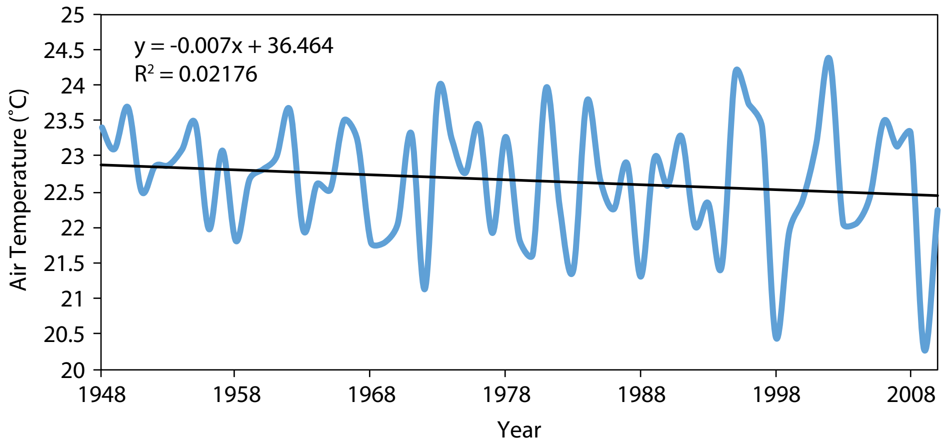
Moist Tropical+



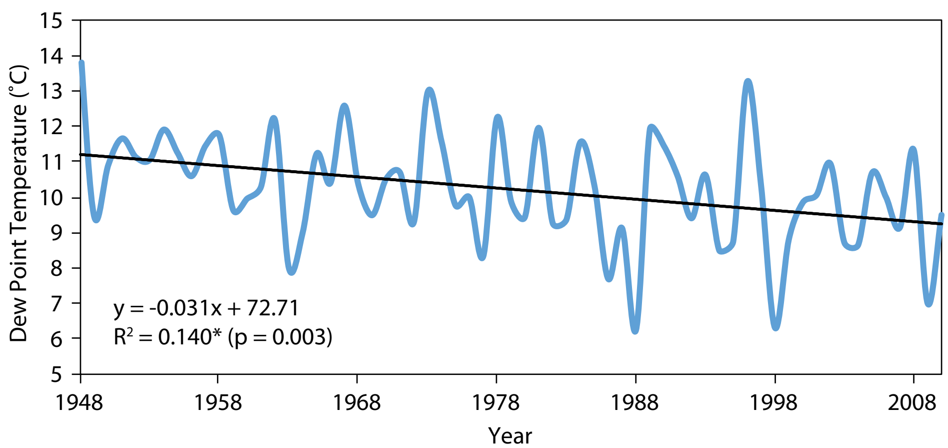
Characteristics of Dry Polar Air Masses in Chicago

All values represent average measurements over a given summer for days classified as dry polar.

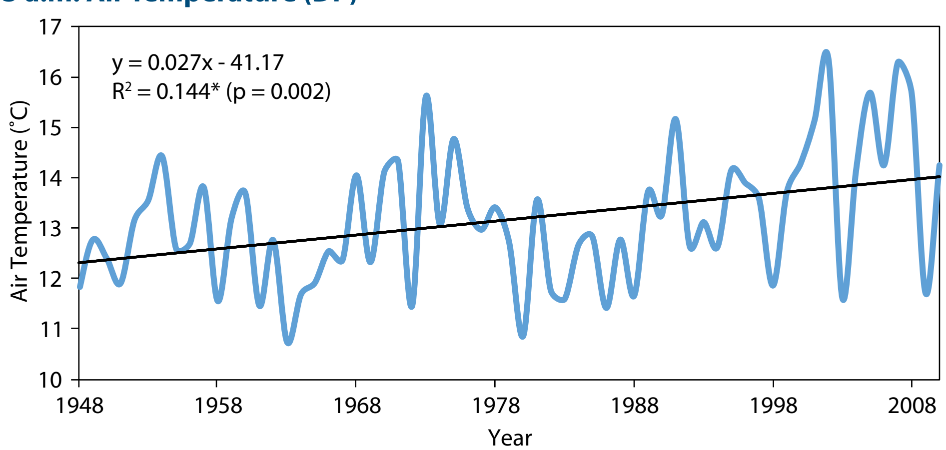
3 p.m. Air Temperature (DP)



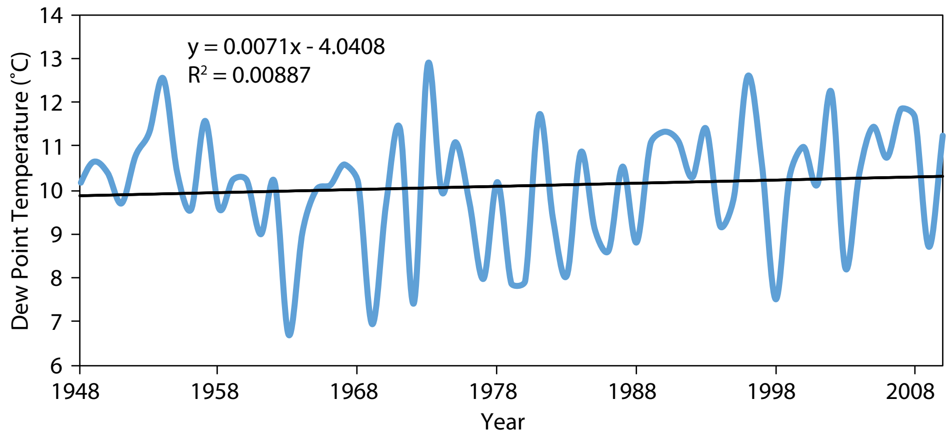
3 p.m. Dew Point Temperature (DP)



3 a.m. Air Temperature (DP)



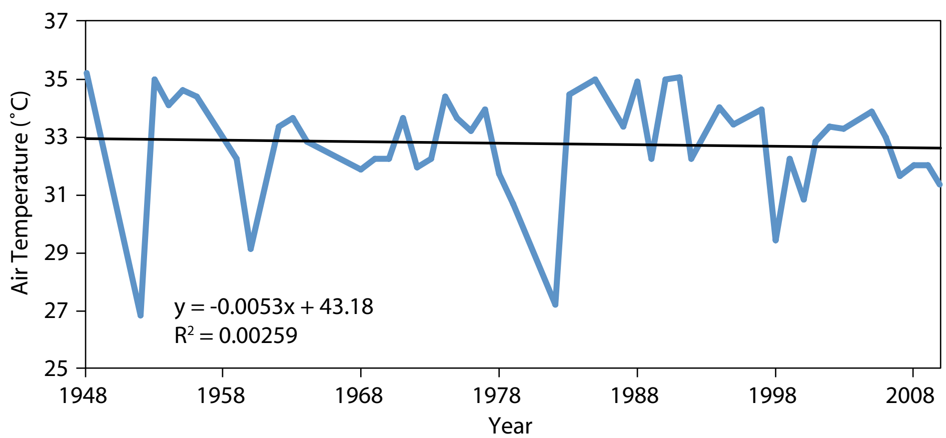
3 a.m. Dew Point Temperature (DP)



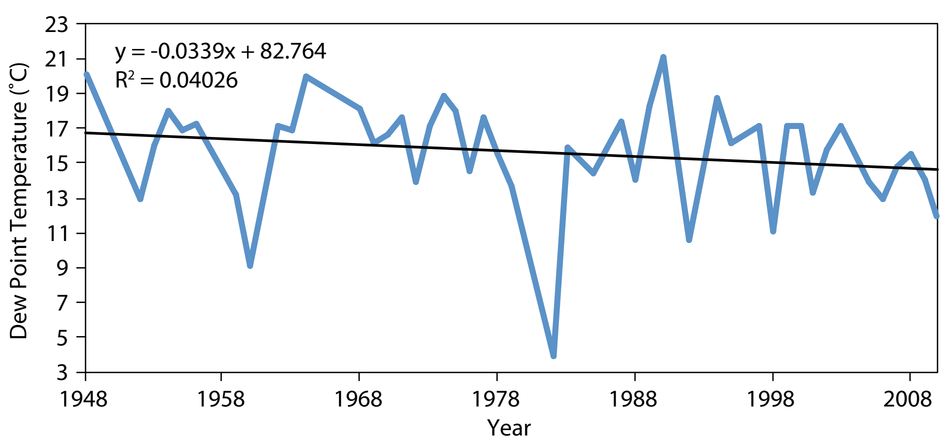
Characteristics of Dry Tropical Air Masses in Chicago

All values represent average measurements over a given summer for days classified as dry tropical.

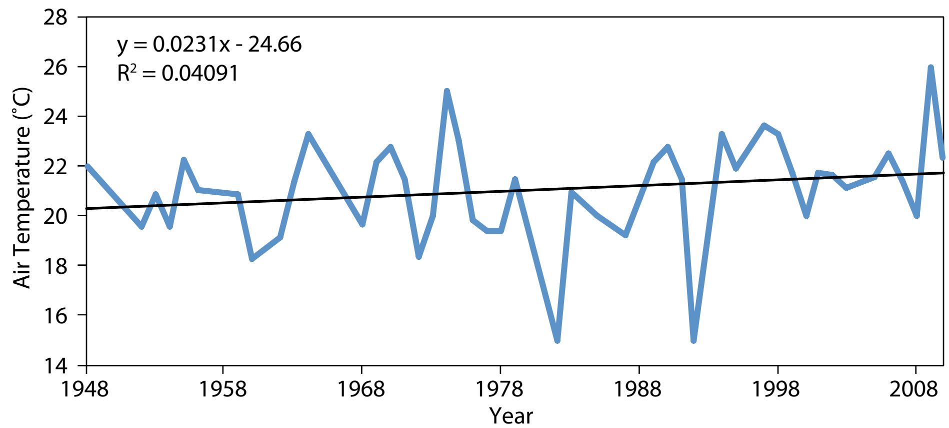
3 p.m. Air Temperature (DT)



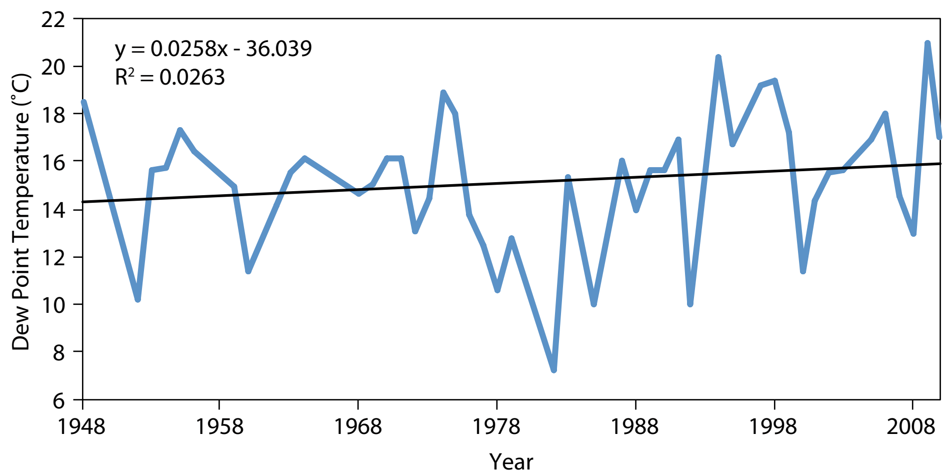
3 p.m. Dew Point Temperature (DT)



3 a.m. Air Temperature (DT)



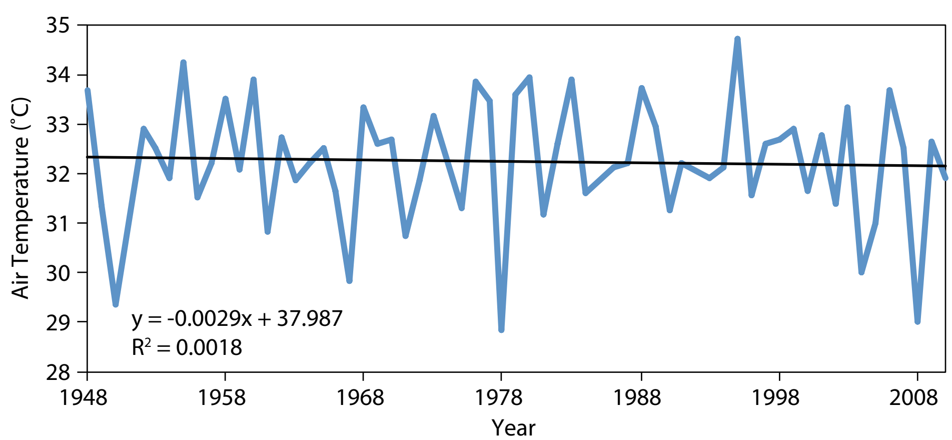
3 a.m. Dew Point Temperature (DT)



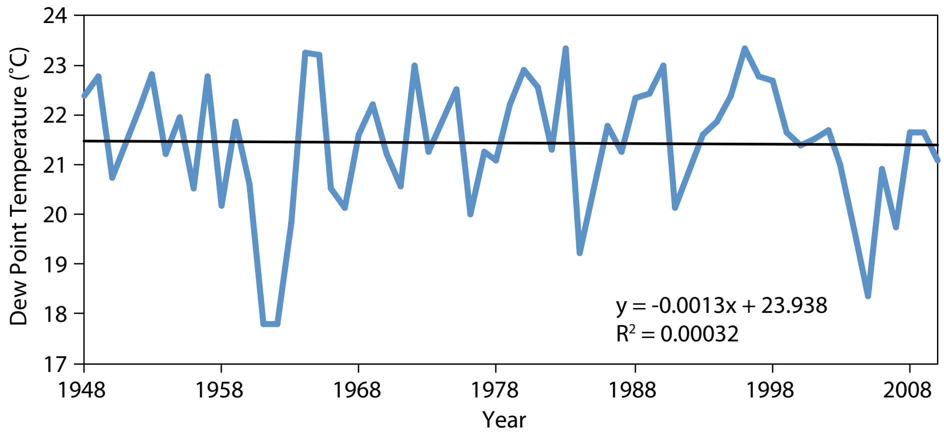
Characteristics of Moist Tropical+ Air Masses in Chicago

All values represent average measurements over a given summer for days classified as moist tropical+.

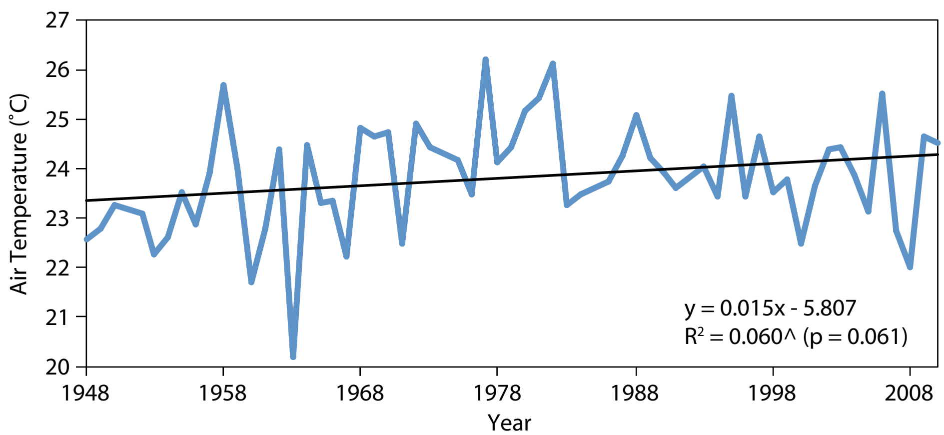
3 p.m. Air Temperature (MT+)



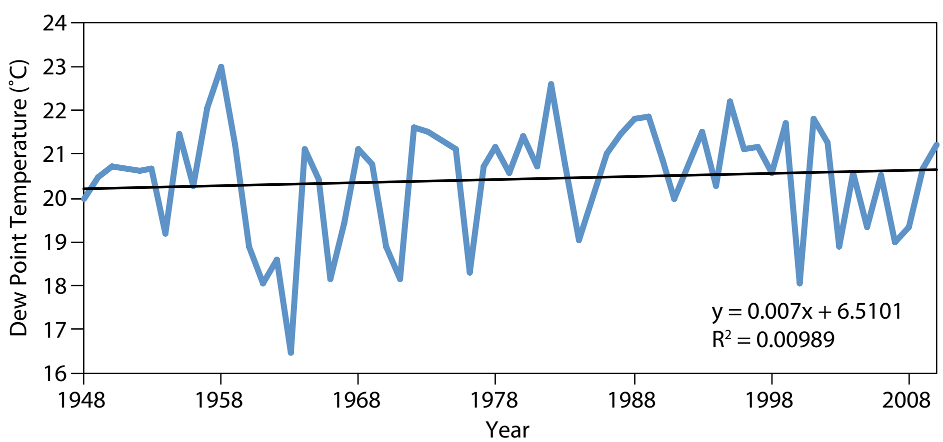
3 p.m. Dew Point Temperature (MT+)



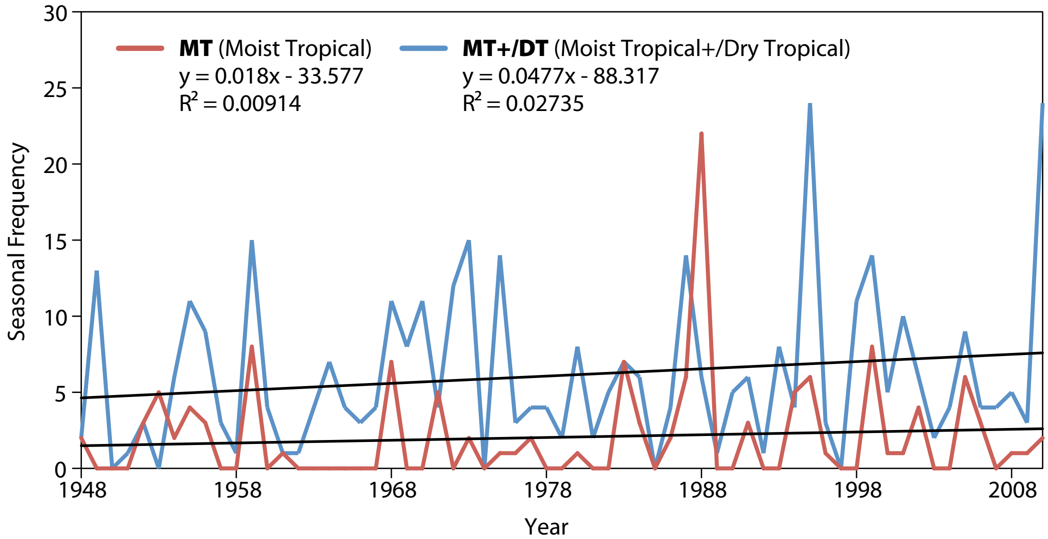
3 a.m. Air Temperature (MT+)



3 a.m. Dew Point Temperature (MT+)



3-Day Consecutive Runs: Chicago, IL



Note: Represents data from 1948 to 2011.

A Closer Look at All Data for Peoria

Peoria's airport—the site of the weather station that recorded the data we used—is roughly seven miles southwest of downtown Peoria, surrounded by residential or undeveloped areas (below).

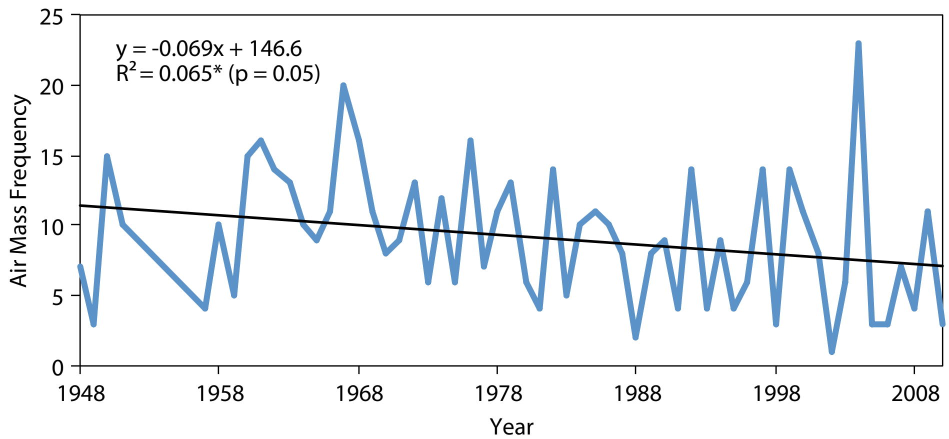
We also evaluated Rockford, IL, which is roughly 90 miles northwest of Chicago, because it is closer to Chicago than Peoria. However, Rockford ended up as an outlier among the 11 cities studied: we found no statistically significant trends in the three air masses of interest, and only one significant trend in air mass characteristics. Because of these variations, we investigated Rockford for anomalies, such as large gaps in data, or a shift in the location of the weather station. However, no obvious difference between Rockford and the other cities emerged. These findings likely highlight variability across the region, and the importance of broad sampling in determining regional trends.

Summary of Statistics for Summer Season (JJA): Peoria, IL

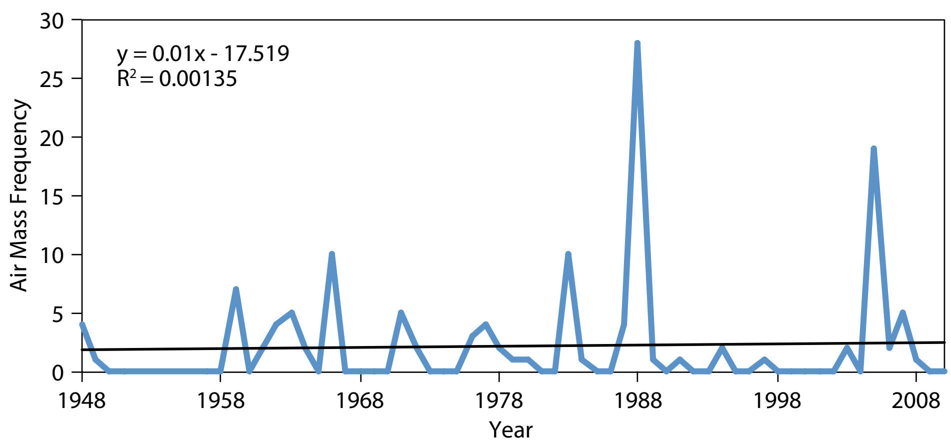
	Air Mass Frequency		Air Mass Characteristics							
			3 p.m. Air Temp.		3 p.m. Dew Point		3 a.m. Air Temp.		3 a.m. Dew Point	
Air Mass	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2
DP	-0.069	0.065*	0.011	0.042	0.016	0.028	0.023	0.106*	0.030	0.125*
DT	0.010	0.001	-0.004	0.002	-0.019	0.010	0.026	0.034	0.010	0.003
MT+	0.094	0.152*	-0.007	0.012	0.021	0.056^	0.013	0.077*	0.018	0.096*

*Significant at the 0.05 level ^Significant at the 0.10 level Disagreement in trend between large and paired smaller city
Agreement in trend between large and paired smaller city DP = dry polar DT = dry tropical MT+ = moist tropical+

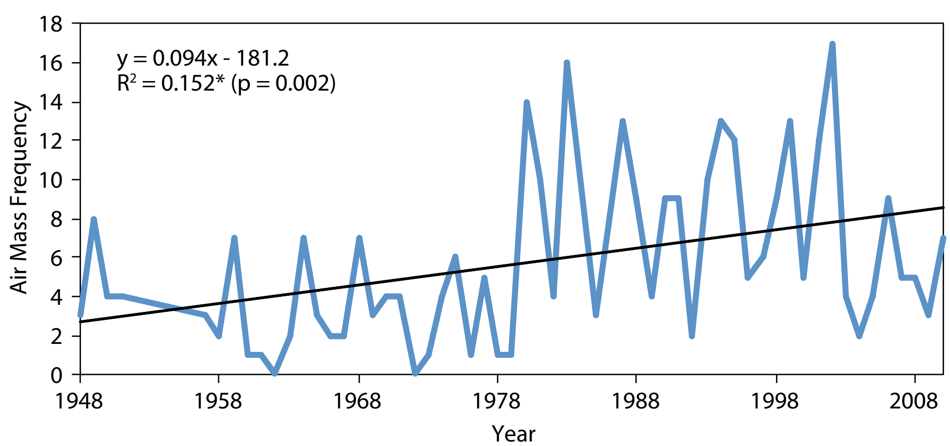
Dry Polar



Dry Tropical



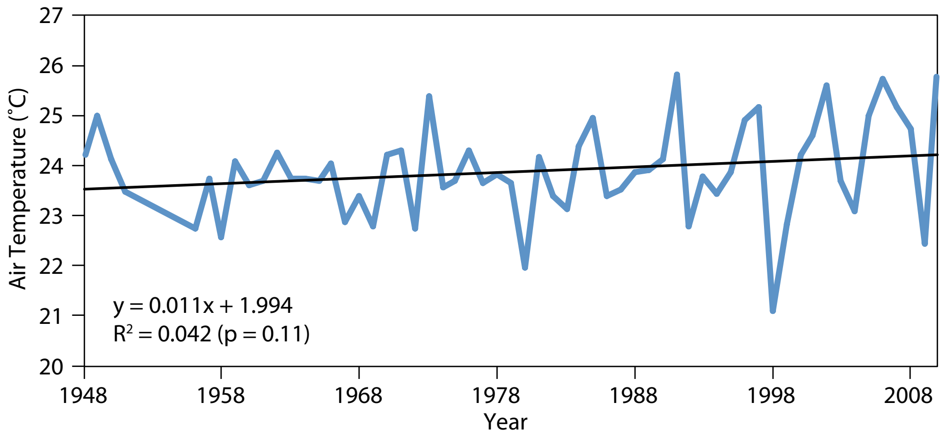
Moist Tropical+



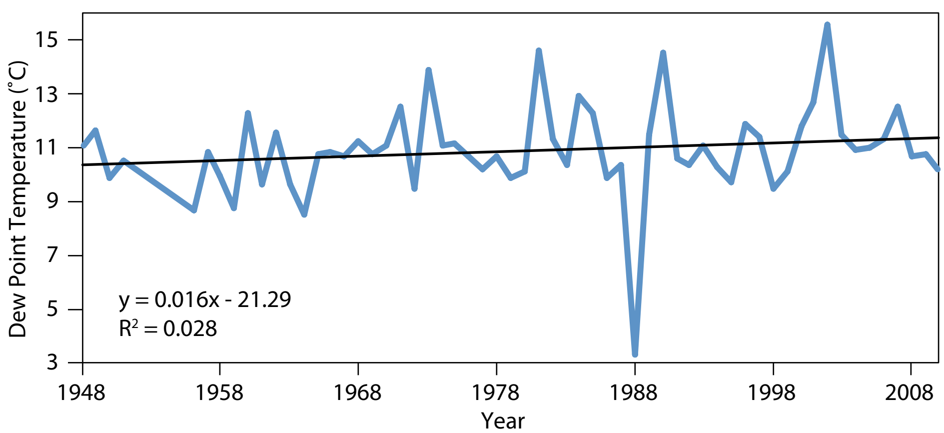
Characteristics of Dry Polar Air Masses in Peoria

All values represent average measurements over a given summer for days classified as dry polar.

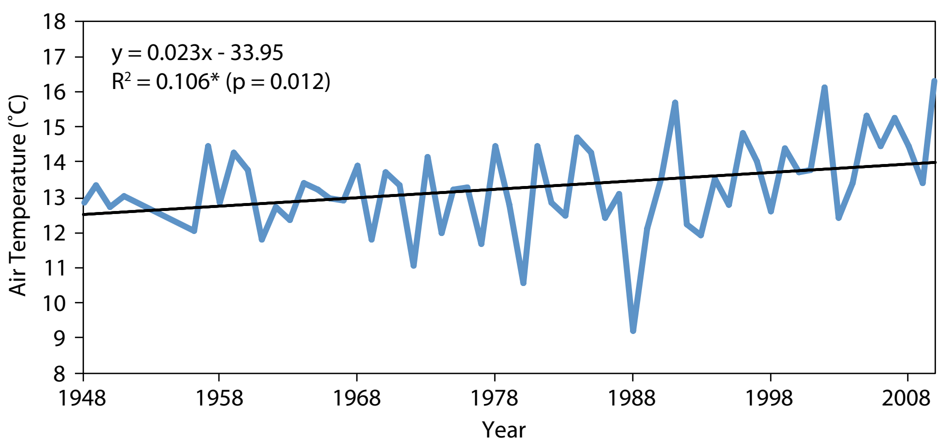
3 p.m. Air Temperature (DP)



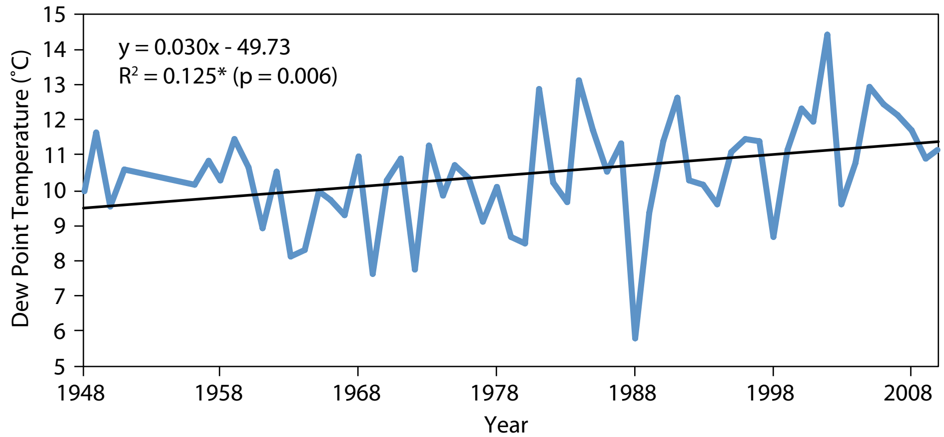
3 p.m. Dew Point Temperature (DP)



3 a.m. Air Temperature (DP)



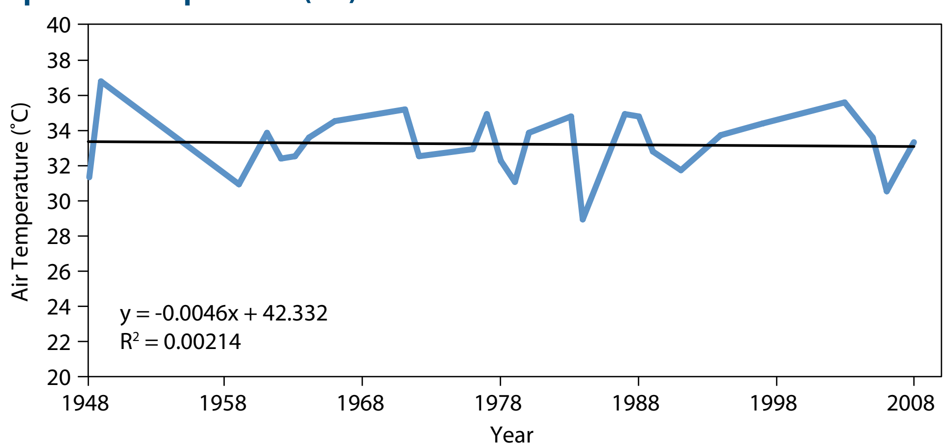
3 a.m. Dew Point Temperature (DP)



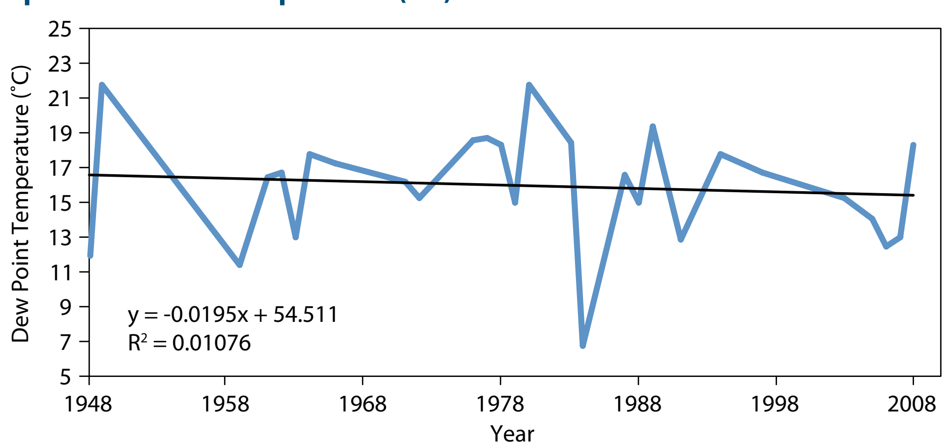
Characteristics of Dry Tropical Air Masses in Peoria

All values represent average measurements over a given summer for days classified as dry tropical.

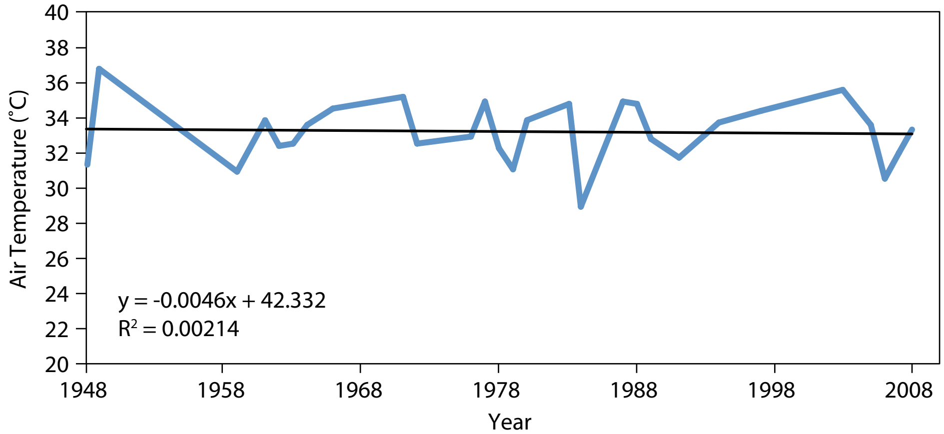
3 p.m. Air Temperature (DT)



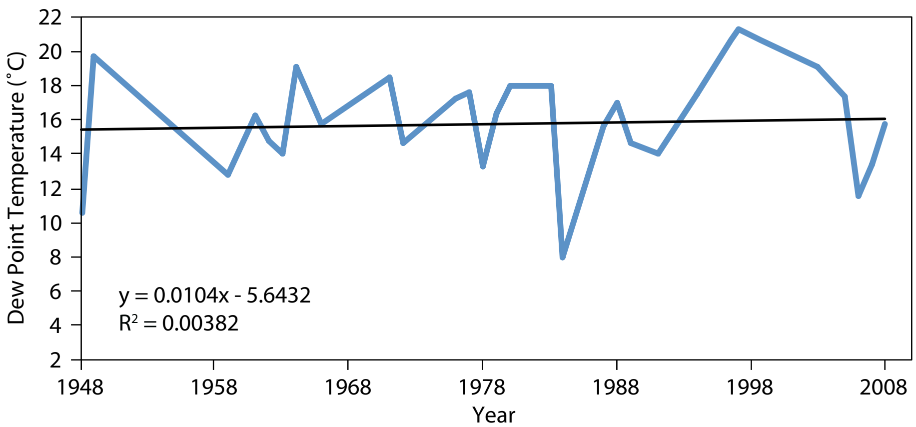
3 p.m. Dew Point Temperature (DT)



3 a.m. Air Temperature (DT)



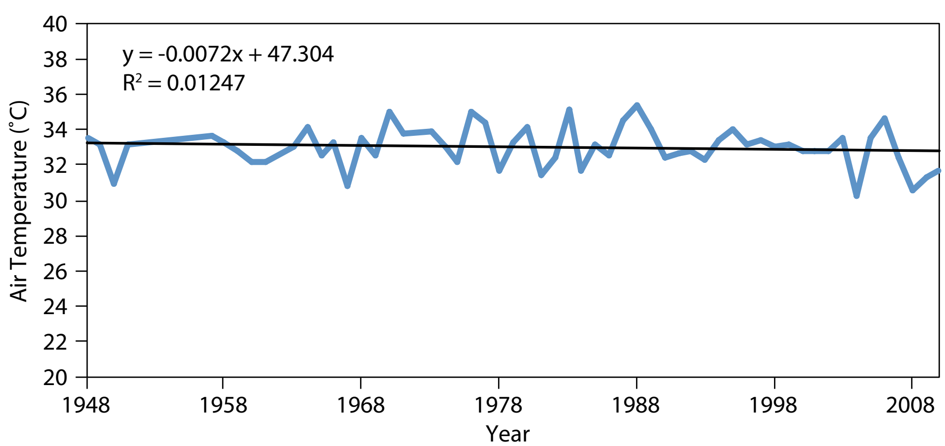
3 a.m. Dew Point Temperature (DT)



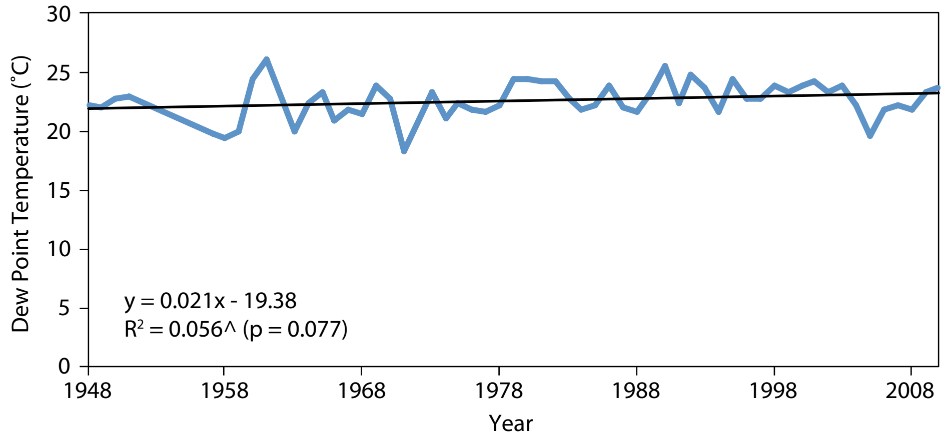
Characteristics of Moist Tropical+ Air Masses in Peoria

All values represent average measurements over a given summer for days classified as moist tropical+.

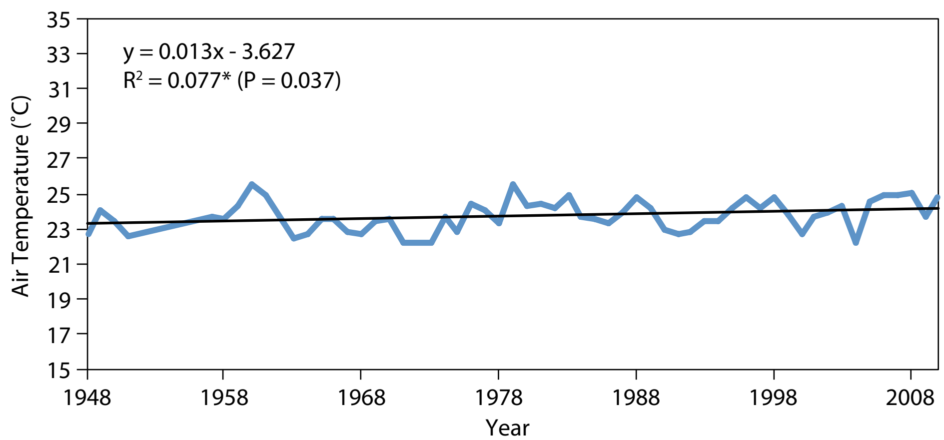
3 p.m. Air Temperature (MT+)



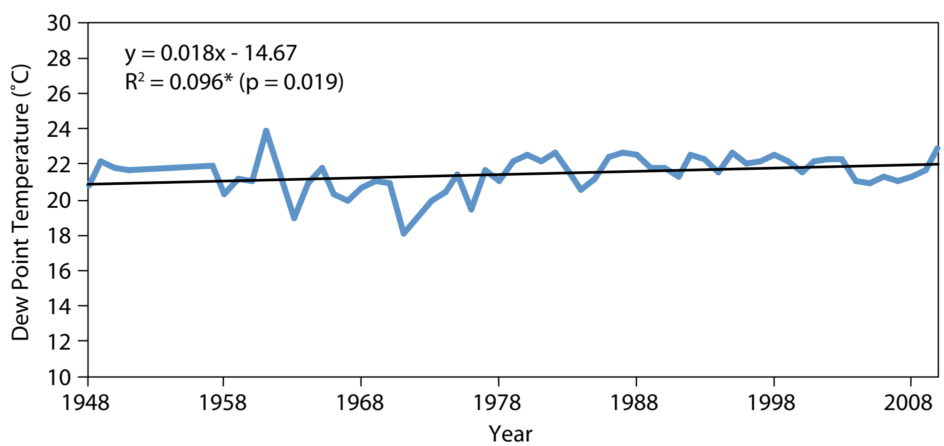
3 p.m. Dew Point Temperature (MT+)



3 a.m. Air Temperature (MT+)



3 a.m. Dew Point Temperature (MT+)



Endnotes

1 For the full list of references see the main report, online at *www.ucsusa.org/heatintheheartland*.

2 A three-day run of moist tropical+ and dry tropical days could occur in any combination. For example, three days in a row of dry tropical count as a single run, as would a pattern such as dry tropical, dry tropical, and moist tropical+. Each three-day stretch of oppressive air mass days counts as a single run. A four-day stretch is therefore counted as two consecutive three-day runs (days 1-2-3 plus days 2-3-4) and a five-day run is counted as three consecutive three-day runs (days 1-2-3, days 2-3-4, and days 3-4-5).

3 Other researchers have used this method of analyzing variables at two times during the day and night to predict heat-related mortality. See, for example, Curriero et al. 2002.

CLIMATE CHANGE AND YOUR HEALTH

Hot, humid days are not just uncomfortable. Extreme heat kills. High temperatures can lead to dehydration, heat exhaustion, and deadly heatstroke. As temperatures rise, public health officials face a difficult challenge.

Heat in the Heartland: 60 Years of Warming in the Midwest analyzes six decades of summer weather in cities in Illinois, Michigan, Minnesota, Missouri, and Ohio. The findings show that many Midwesterners are already living with more hot and humid summer days, hotter and more humid summer nights, and more dangerous heat waves—as well as fewer cool days to bring relief from the heat. Extreme heat is not only tomorrow's problem: it is already affecting Americans across the Midwest.

The United States has the technology to reduce harmful global warming emissions, and the knowledge to protect the public from extreme heat. In fact, as this report shows, Midwest cities are already taking some lifesaving steps. The choices we make today to adapt and prepare for a warming world will affect the health and well-being of ourselves, our children, and our descendants long into the future.

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Union of Concerned Scientists

Citizens and Scientists for Environmental Solutions

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The Union of Concerned Scientists is the leading science-based nonprofit working for a healthy environment and a safer world.

The report and technical appendix are available online (in PDF format) at *www.ucsusa.org/heatintheheartland.*

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